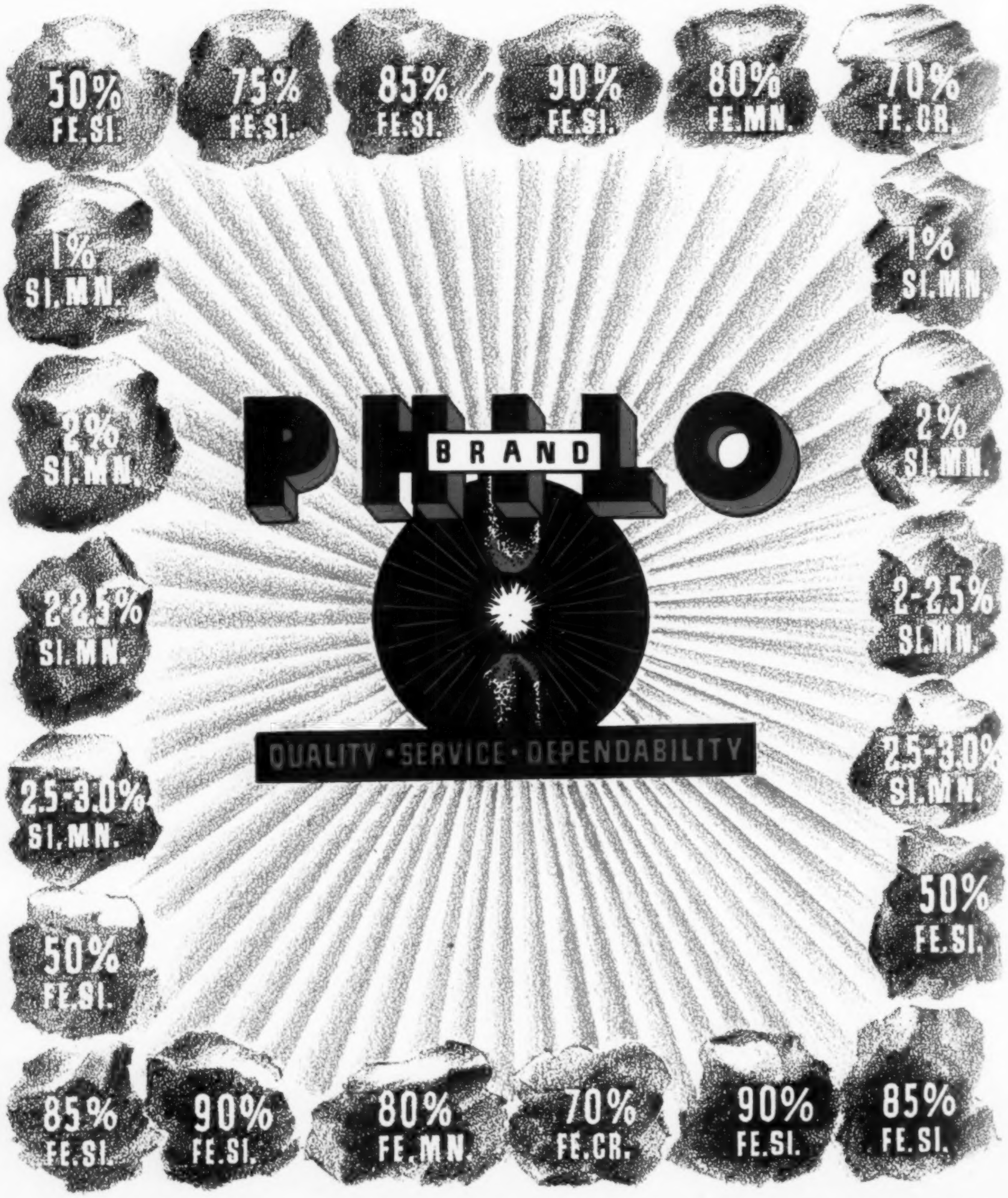
OCT. 1934

Metal PROGRESS

THE AMERICAN SOCIETY FOR METALS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METAL PROGRESS

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October, 1934

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Ernest E. Thum, Editor

THE compact, self-contained and highly specialized nature of the Timken organization enables it to get to the root of a customer's or prospect's steel requirements without loss of time. Furthermore, personal control is direct and close enough at all times to assure instructions being accurately followed. Isn't this the kind of organization with which you would like to do business?

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TIMKEN ALLOY STEELS

ELECTRIC FURNACE AND OPEN HEARTH • ALL STANDARD AND SPECIAL ANALYSES

ALLOY and TOOL STEELS

● Progress in the S. A. E. steels has been in better steel making and better appreciation of the possibilities of each alloy. . . . Trend of new steels has been toward lower alloy contents; they are used as rolled and are interesting railroad executives and naval constructors. . . . Tool steels are being made to closer chemical limits and with less decarburization at surfaces. . . . ●

ADVANCEMENT IN LOW & MEDIUM ALLOY STEELS

WITHOUT attempting to lay down a definition of "alloy steel," let us include in it some of the high strength commercial steels which have no alloys intentionally added except a considerable excess of the always-present manganese and silicon. Such a group of alloy steels might be subdivided into two main divisions, first, engineering alloys such as the S.A.E. specifications would call for, and second, the high strength steels containing lower alloys, as recently developed.

There have been remarkably few changes in the chemistry of the S.A.E. steels in the last 20 years. Steel and alloy manufacturers have devoted an enormous amount of time and attention, however, to the studies of the properties of each of the familiar alloy series, and the resulting information enables the user to choose a steel and a treatment likely to suit the peculiarities of the part under study. Likewise the steel makers have given much study to the proper methods of refining, casting, and rolling, with the result that the physical properties and the uniformity of the material in the hot rolled condition are undoubtedly superior to those of ten years ago.

Attention has recently been given to the subject of grain size; it is still actively in the minds of both producer and consumer, as is shown by the dozen discussions on various phases of this subject scheduled for the National Metal Congress in New York this month. R. L. Wilson wrote a paper for METAL PROGRESS in August which presented the practical aspects of grain size in alloy steel. His general conclusions are that the coarse grained steels have good machinability, intense hardening, easy coarsening of structure, and are good for high temperature service above 950° F. (as in oil refineries). The fine grained steels are recommended for economical case hardening, good toughness, superficial hardening of the direct hardening steels, small amount of warpage in hardening, best mechanical properties of untreated steel, and service at temperatures below 950° F. (as in steam power plants).

There has been a growing demand from consumers of high grade alloy steels for material more closely specified as to grain size, adaptable to economical production in forge and machine shop. Only during the past three years has control of this property been extended to open-hearth steel. Where formerly a spread of four numbers was the best that could be guaranteed (that is, shipments would range from, say, grain size 5 to grain size 8), definitely fine grain (size 6 to 8) can now be regularly secured.

Nickel Steels

While nickel steel was not the first alloy steel to be used commercially, it certainly was the first simple alloy steel to be used in a way we now believe alloy steels should be used — namely, in a carefully processed and heat treated condition to develop valuable characteristics impossible to

secure in simpler steels. Historically, also, it is of interest to know that the first application to a production job in America, other than isolated instances for large shafting, was in 1895, when Tom Towne prevailed upon his firm (Union Drawn Steel Co.) to get some armor plate from Carnegie Steel Co. and roll and draw this 5% nickel steel into "figure-8" sections. These were then fabricated into bicycle sprocket chains by Whitney Mfg. Co. for the Pope bicycle and gave much better service than carburized carbon steels.

Long experience (long, as regards the age of alloy steel) with nickel steel is responsible in part for its popularity. Nickel introduces no complications in the steel refining process, and it is relatively easy to fabricate metal in the as-rolled condition with yield point of 50,000 psi. (compared with 35,000 psi. for carbon structural steel). Hence its popularity with bridge builders for long spans where weight of members is an important consideration, and where heat treatment of heavy sections is frowned upon.

As a matter of fact, we have more information on the heat treatment of heavy sections of nickel steel than any other alloy, and many firms have been quite successful in such important work with armor plate, big gun tubes, heavy shafts for ships, and electrical machinery. Its success here is partly due to the fact that the commercial alloys are relatively insensitive to minor variations in heat treatment, inseparable with large pieces or with mass production.

The net of accumulated experience is that nickel steels warrant careful consideration by all intelligent metallurgists when the maximum ductility, toughness, and endurance are required in important parts whose exact working stresses are doubtful or, if known, likely to be exceeded occasionally. This situation can be expressed qualitatively by the statement that crankshafts, connecting rods, rocker arms, and main gears in engines for aircraft, rail cars, and racing boats are usually made of the 3½ or 5% nickel steels, and that they are widely used in excavating, mining and quarry machinery where excessive shocks are frequent. Quantitatively the facts may be stated by averaging a large number of tests on 0.40% carbon steel heats, some with 3½% nickel and some without alloy elements, but all heat treated to the same ultimate tensile strength. These are shown in the table at the head of the next column.

	Steel S.A.E. 2340	Steel S.A.E. 1040
Carbon	0.40%	0.40%
Nickel	3.5 %	none
Ultimate strength	150,000 psi.	150,000 psi.
Yield point	137,000 psi.	112,000 psi.
Elongation in 2 in.	18%	9%
Reduction of area	56%	34%
Izod impact	36 ft-lb.	13 ft-lb.

Some study has recently been given to the problem of toughness of steels at low temperatures — not only the sub-zero ranges encountered by aircraft at high altitudes in winter, but also for making carbon dioxide refrigerants, for purifying gases at liquid air temperatures, and for de-waxing of petroleum products. Strong carbon steels containing 0.40% carbon and more become brittle at arctic temperatures; experiments also show that austenitic alloys like low carbon 18-8 and monel metal, which have no phase change induced in them at low temperature, have their toughness practically unimpaired even in liquid air. Intermediate are the mild carbon steels and various common alloy steels in the annealed or normalized condition which maintain their original toughness reasonably well to some temperature below zero but lose most of it on going colder.

The 3% nickel steels have shown quite well in laboratory tests. Ability to be welded with special filler rods into joints having much the same properties as the adjoining plate have warranted their use in a number of vessels working at 400 psi. at −310° F. Charpy tests on notched specimens of plate and weld metal are shown in the table below. At −300° F. these values drop to 5 or 6 ft-lb., which, while low, seem to be adequate in view of the satisfactory use of the equipment. Unnotched Charpy bars, tested cold after immersion in liquid air, bend 90° to clear the hammer without cracking.

Other studies suggest that the low temperature toughness of steels may be increased by combining a carbide-forming element like va-

Charpy Impact (Unnotched Bars) at Low Temperature

	+75°F.	+25°F.	0°F.	-25°F.	-50°F.	-75°F.	-100°F.
Plate, 3% nickel steel							
As rolled	46	42	36	37	36	29	35
Stress relieved at 1200°F.	55	46	42	36	35	33	28
Weld metal							
As welded	40	43	53	52	37	36	36
Stress relieved at 1200°F.	39	47	34	40	56	38	34

Nickel Steels Are Found in Engine Parts On All Fast Craft

pered at about 300° F.) This relatively simple treatment after carburizing avoids the expense of multiple heatings, and much of the resultant distortion. Experience also shows that many economies result in the manufacturing line, and in service this steel has excellent wear resistance.

From the steel maker's viewpoint, the nickel-molybdenum steel is desirable because none of the alloy is lost during refining, or during remelting of the scrap.

The result is that the single quenching analysis has become a favorite among automotive part makers, where mass production and close metallurgical control have given a high degree of uniformity and reliability for it in many parts, including transmission gears, especially when the steel has been properly made and prepared so it can be quenched direct from the carburizing pot. (An interesting recent application of S.A.E. 4615, not heat treated, is for condenser tubes using salt or brackish water.)

Since a saving of half the nickel was effected by a little molybdenum in substituting S.A.E. 4615 for 2315, a similar effort has recently been made to substitute a 3½% nickel steel with 0.25% molybdenum for the 5% nickel steels ordinarily used for very severe duty, as carburized gears and pinions in trucks and busses. Similarly a 0.40% or 0.50% carbon analysis (1.75% Ni, 0.25% Mo) has been found suitable for oil hardened gears, having the qualities of machinability and hardening without warping.

Chromium-molybdenum steel for rear axle shafts is an interesting recent development in low cost alloys. S.A.E. 4140 (1% chromium, 0.20% molybdenum) is being used in the 1934 models by six cars in the $1000-up class, one truck, and by one parts manufacturer of light weight axles. Oil quenched from 1525° F., they are drawn, depending on type and service of the shaft, as follows:

Draw (approximate)	1050°F.	900°F.
Brinell hardness	311 to 340	364 to 418
Yield strength	130,000 psi.	150,000 psi.
Tensile strength	155,000 psi.	170,000 psi.
Elongation in 2 in.	18%	14%
Reduction of area	50%	48%

nadium with austenite-forming elements like nickel. This fact, in conjunction with what we know about the mechanism of embrittlement of certain austenitic and ferritic alloys after long stay at moderate or elevated temperature, indicates that the origin of the embrittlement may be the same — namely, separation of sub-microscopic particles of carbide phase — and the cure may be effected by alloying with some strongly carbide-forming element like titanium or columbium and by some preliminary stabilization treatment which will precipitate and agglomerate and so render harmless the phase which otherwise would separate and embrittle the metal at low temperature.

Molybdenum Steels

Nickel-molybdenum steels are not new as regards their application to roller bearings and gears, but one or two new analyses for specific purposes have been recently put on the market.

As is well known, the nickel-molybdenum steel was developed for case-hardening. Carburized nickel steel gears, for instance, are preferred by many to direct hardened chromium steel gears for their greater toughness and resistance to wear and shock in severe service, but they require a double treatment to refine the low carbon core and the high carbon case. It was discovered that the 1.75% nickel, 0.25% molybdenum steel (S.A.E. 4615) of fine grain size will resist grain growth at carburizing temperature so that the carburized part is tough if oil quenched from the pot (sometimes they are tem-

As to the manganese-molybdenum steels, it has been established that 0.25% molybdenum will improve the Izod impact values of medium maganese steel at least 10%, a change associated with a fine grained microstructure. Molybdenum also appears to improve the uniformity of response to heat treatment, decreasing the number of rejects beyond specification limits when a medium maganese steel without molybdenum is carburized.

Medium manganese steels with molybdenum carburize about 25% deeper in a given time than the nickel-molybdenum steels (S.A.E. 4615). Transverse strength of hardened bars is about the same, but the impact strength of the case hardened and heat treated Izod bars is inferior. Vickers hardness of the steel, oil quenched from the pot, is 715, and this hardness is maintained to a depth of 0.035 in. These characteristics indicate its usefulness for inexpensive gears and bearings, for instance, where the load is steady and not severe, and lubrication somewhat deficient at times.

Carbon-molybdenum steels have had a recent revival in interest, due to the fact that C. H. Wills, one of the War-time proponents of the then-novel alloy, is studying its applications to automotive engineering for the Chrysler Corp. No public statements as to the trend of plant practice have yet been made other than that such a steel is being used for the helical springs in the new front wheel suspensions on 1934 Chrysler models.

Possibly many of the supposed disadvantages of carbon-molybdenum steels will evaporate when real metallurgical attention is given to them. At any rate, its characteristics as an alloying element (the promotion of air hardening and hardening at depth, the interference with grain growth, the widening of the heat treating range) all indicate that it may improve a good carbon steel, and be a useful alloy in its own right.

Chromium Steels

Chromium, also, is an element appearing in alloys with other elements, such as nickel and vanadium, and there is little to report about these S.A.E. steels, other than that which has already been said about a better appreciation of the utility of each particular analysis which indicates an important future for the 5100 series.

Remarkable advances have occurred in the last five years in the field of stainless and heat resisting steels, all of which depend on high chromium for their properties, but this is discussed in another section of this issue (page 23). Studies of plain chromium steels containing up to 6% chromium have also developed interesting and valuable possibilities.

This whole matter was discussed at length by S. M. Norwood in the last issue of Metal Progress, and consequently need not be repeated here. Suffice it to say that air hardening takes place even in 1% chromium steels if the carbon is much above 0.35% (as indeed was found out as early as 1868, much to the annoyance of Capt. Eads who was then building the arch bridge across the Missouri at St. Louis, and the early steel mill which broke many a roll in making the required shapes). If chromium is at 3%, the steel air hardens with as little as 0.10% carbon, with a good combination of toughness and hardness, and these grades with or without molybdenum and nickel are well suited to such parts as rock crushing equipment and dipper and dredge teeth. Railroad rails with 3% Cr, 0.30% C are giving excellent service on heavy main line track, as shown by Professor Waterhouse in this magazine last April.

Low carbon steel with 4 to 6% chromium (and 0.5% molybdenum to take the carbon away

Chromium Steels Are Favored for Hardness and Wear Resistance. Photograph of a hardened roll in grinding machine by John P. Mudd

om the chromium so the latter can act as a corrosion resistor, or enough titanium to eliminate the air-hardening tendency so the material can be worked) makes excellent tubing, castings, and other equipment for moderately severe service in oil refineries — too severe for plain carbon steels, which may have only from 10 to 20% of the life. This useful steel is midway between the engineering alloy steels and stainless.

At the low end of the chromium range is the 1¼% chromium low carbon steel, containing 0.75% silicon and 0.50% molybdenum. These low cost steels, in the form of tubes, have a life in petroleum equipment two or three times as long as plain carbon steel and considerably greater creep strength at 1000° F. — possibly due to the silicon and molybdenum content. Corrosion resistance increases with the chromium.

Similar low chromium steels containing 0.45% carbon, and therefore air hardening, are useful under high stress at 1000 to 1100° F., for bolts and studs, on account of their high creep strength. A steel with 2.25% chromium and 0.50% molybdenum has been made into tubes for chemical plant, with a good balance of creep resistance, corrosion resistance, and cost.

Relative oxidation and creep resistance of these steels are given by Wiewel and Wilson in *National Petroleum News*, August 1, as follows:

High Temperature Properties of Low Alloy Steels

Composition	Loss by Oxidation in 1000 hr. at 1200°F.	Stress for 1% Creep in 100,000 hr. at 1000°F.
0.15% carbon steel	3.246 g.	3,200 psi.
4 to 6% chromium	1.086	6,000
Same with 1% W	0.802	5,650
Same with 0.5% Mo	1.198	7,000
0.50% Mo steel	4.216	9,600
1.25 Cr, 0.75 Si, 0.50 Mo, 0.15 C	1.785	15,000
1.25 Mn, 0.25 Mo, 0.15 C		8,300
1.25 Cr, 0.75 Si, 1.0 W, 0.30 V, 0.45 C		13,500
18% Cr, 8% Ni		15,000

Another marginal steel on the lower end of the alloy steel range is the so-called cromansil steel, containing about 0.50% chromium, 1.25% manganese, and 0.75% silicon. Silicon increases the yield point without detriment to the machinability; manganese is important in raising the tensile strength, and chromium appears to intensify these effects without impairing an excellent ductility and toughness. This steel has been promoted as a low alloy of good properties in the as-rolled condition.

It is therefore being used where a high ratio of strength to weight is of importance, as for welded engine beds, underframes, and other parts in the construction of streamlined high speed passenger cars, light weight railroad equipment of conventional appearance, diesel engine bases, and dredging buckets for deep sea work. It has recently been accepted by the A.S.M.E. Boiler Code Committee for use in boilers and pressure vessels under Code requirements.

Cromansil steel rivets possess definite advantages over the usual high strength rivets. They are less brittle, are ductile enough to be chipped and caulked when cold, and can be driven by a skilled crew without observing any unusual precautions. They have high shear strength; using them the designer can take full advantage of the high strength steels in riveted structures.

Vanadium Steels

We have come by almost insensible steps in the chemistry of steels to those which contain rather unusual amounts of the elements silicon and manganese, with or without fractional percentages of other alloying elements. Interesting developments have taken place by adding vanadium to this same general chemical classification. By this means excellent coil springs, locomotive forgings, high elastic castings, high strength structural plates and shapes, and miscellaneous small automotive parts may be made.

Taking up the last mentioned, it has long been known that medium-stressed parts on automotive chassis and engines have been made either with some of the less expensive S.A.E. steels, somewhat deficient in general workability, or if cost was to be saved, a change was made to the plain carbon steels, sometimes high in manganese and silicon. In such parts as steering arms, axle shafts, bolts, brackets, and universal joints, the maximum forgeability and machinability has been the prime object. Hence the rise of intermediate alloy steels, specifically suited to the practical and economical requirements of mass production.

An example is one containing 0.35% chromium and 1.25% manganese, to which 0.10% vanadium has been added. Carbon may vary from 0.25 to 0.45% depending upon strength and other requirements. There is enough vanadium present to refine the grain size as rolled and prevent grain growth at forging temperatures. Normalizing not only puts such a steel in good condition for machining, but frees it from

internal stresses, eliminates warping, and produces the maximum of uniformity. As normalized the physical properties will vary from 70,000 to 78,000 psi. yield (depending on the carbon in the above-quoted range), 92,000 to 115,000 psi. tensile strength, 30 to 25% elongation in 2 in., 67 to 60% reduction of area, and 85 to 40 ft-lb. Izod impact.

Medium manganese steels containing vanadium have been brought to importance in the form of castings, forgings, and rolled plates and shapes. C. E. Sims, only last month in METAL PROGRESS, indicated the principles used in casting and heat treating such a steel (0.35% carbon, 1.40% manganese, and 0.10% vanadium). Such castings easily pass the newly adopted A.S.T.M. specification A 148-33 T for Class *B* alloy steels, Grade No. 2, covering high elastic castings. Requirements specified and those daily achieved, as shown by the average results, of about 20 types of castings made for the new Union Pacific high speed train, are as follows:

	Specification	*Average Performance*
Yield strength	*60,000 psi.*	*64,000 psi.*
Ultimate strength	*90,000 psi.*	*91,000 psi.*
Elongation in 2 in.	*25%*	*27%*
Reduction of area	*50%*	*54.8%*

Izod impacts on this steel are very good, Mr. Sims recording values in his article on the order of 48 ft-lb. on a casting showing the high tensile strength of 101,000 psi.

A series of 17 driving axles, piston rods, and crank pins made of slightly different composition (C 0.25%, Mn 1.60%, Si 0.25%, V 0.16%) after normalizing and tempering gave the following results:

	Maximum	*Minimum*
Yield strength	*78,250 psi.*	*60,000 psi.*
Tensile strength	*99,000 psi*	*91,000 psi.*
Elongation in 2 in.	*32%*	*25%*
Reduction of area	*67.5%*	*51%*
Brinell hardness	*207*	*174*
Izod impact (average of two)	*98.5 ft-lb.*	*73.25 ft-lb.*

Penetration of hardness on quenching, and general uniformity of physical properties are shown by tests on a 12½-in. locomotive axle, forged, water quenched from 1650° F., and tempered at 1200° F. Brinell hardness at edge was 222, at center was 197. Tested radially, the ductility was lowered about one-tenth from the longitudinal values.

High Strength Structural Steels

Further reduction of the carbon to 0.15% brings these low alloy steels in the range of high strength structural steels. Silicon steels, so called, were introduced in America about 1917, and have gone into some large bridges and buildings. Medium manganese steels are a later development, and have been used for the main compression members on one of the bridges recently built near New York. High carbon structural steels have also been used for marine purposes, either in the as-rolled or the normalized condition.

Of course, common structural steel can be improved by proper treatment. For instance, the true elastic limit of mild structural steel is low and variable, but by simply normalizing a properly deoxidized steel, this can be brought up to an average of 37,500 psi.

For marine work the last-quoted figure is hardly high enough; a proportional limit of 40,000 psi. and ultimate strength of 85,000 psi. can be had with a plain steel containing 0.30% carbon, 0.90% manganese, and 0.25% silicon. However, either this steel or the medium manganese steel would be deficient in impact strength alongside a welded seam, where the grain was coarsened and the metal hardened by the heat. (This matter may be mitigated if the original steel had a very fine grain size.)

The 0.15% carbon steel with 0.10% vanadium, 1.30% manganese, and 0.20% silicon, has a 70 ft-lb. Izod impact test as rolled, and retains this toughness remarkably after welding due to the ability of vanadium as a grain refiner and corrector of air-hardening tendencies. The yield point ranges from 60,000 to 72,000 psi. and the tensile strength from 83,000 to 95,000 psi. in the as-rolled condition. Its endurance limit is also high, on the order of 55,000 psi., all of which makes it most attractive to engineers who are interested in saving weight in structures.

Copper as a Steel Alloy

Traditionally copper has been considered as poison for steel. Phosphorus also has had a bad name. Both are now known to be good when used intelligently.

Up to quite recently, the principal accepted use for copper was for resistance to atmospheric corrosion, it having been clearly established that about 0.25% in mild steel, or a similar amount plus a little molybdenum *(Continued on page 1?)*

in open-hearth iron) is excellent. About 1,000,000 tons of such sheet and plate are made in normal years. Seamless tubing with up to 1% copper makes good oil well casing; in combination with perhaps half as much molybdenum it has good corrosion resistance combined with strength at moderate temperatures, which indicates numerous applications in the steam power, oil refining, and the chemical process industries generally. High strength steel castings containing copper have also been made for years and installed in steam shovels and similar heavy excavating equipment. Considerable copper-molybdenum steel, with and without chromium, have been made into rolled products.

Researches under way at Battelle Memorial Institute, sponsored by Copper & Brass Research Association, will doubtless do much to clear up the metallurgical facts and dispel superstitions regarding this element's effect on fine steels. It has already been shown that steels with 1% copper can have their yield and tensile improved by 20,000 psi. with no decrease in ductility by reheating the air cooled pieces 4 hr. at 900° F. — an example of "precipitation hardening." The light "alligator markings" on rolled steels of this analysis are prevented by heating in a non-scaling atmosphere or by adding 0.25% nickel.

B. D. Saklatwalla of Vanadium Corp. of America has studied the effect of copper on the corrosion resistance of steels, and finds that low carbon steels (0.10% C max.) containing about 1% chromium, with 0.40% copper and 0.75% silicon have about twice the resistance to atmospheric corrosion as copper-bearing steel. Such steels are now beginning to get into commercial production and are promoted for their strength and corrosion resistance. (Strength is due in part to 0.10 to 0.15% of phosphorus, which is permissible with the chromium.) Their cost is about double that of carbon structural steel but the yield strength is also nearly twice as high (50,000 to 60,000 psi.).

Some 50 passenger cars are being constructed largely of this copper-chromium-silicon steel for the New York, New Haven and Hartford Railroad, wherein 25% of the weight is being saved. Similar results are being achieved on an order of new freight cars by the Baltimore & Ohio Railroad. Extensive use of welding is being utilized to increase the weight saving to 35% (146,000 lb. down to 96,000 lb.) in a lot of 52 day coaches under construction by the Chicago, Milwaukee & St. Paul Railroad.

At the METAL SHOW

BETHLEHEM'S EXHIBIT at the National Metal Exposition will contain a working model of its electrically operated bar heat-treating plant.

This plant has placed Bethlehem in an exceptionally favorable position to meet industry's increasing demand for heat-treated steel. It is the largest in the world devoted to the hardening and annealing of mill-length bars, and embodies the most recent improvements in heat-treating practice, applying on a commercial scale the exact methods of the laboratory. The timing of all operations is automatically controlled.

The working model at the exhibit shows the bars in motion, and reproduces the furnaces in which they are preheated, then heated for quenching. It shows the automatic crane which removes the bars and lowers them into the quenching tank, and the furnaces, also electrically operated, in which the quenched bars are annealed.

Visitors to the Exposition and the National Metal Con-

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REPUBLIC STEEL CORPORATION

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STAINLESS STEELS . .

● An increasing demand during the depression period . . . 18-8 gradually lowered in carbon content to stabilize against high temperature. . . . Paper and dye industry finding use for a high molybdenum variety . . . Cold rolled 18-8 strip formed into structural members for high speed train bodies . . . Plain chromium steel strip in tonnage for automobile trim . . . Utility demands in various industries more important than luxury demands of stainless steel for show purposes ●

A RAPID VIEW OF . . .

THE STAINLESS STEELS

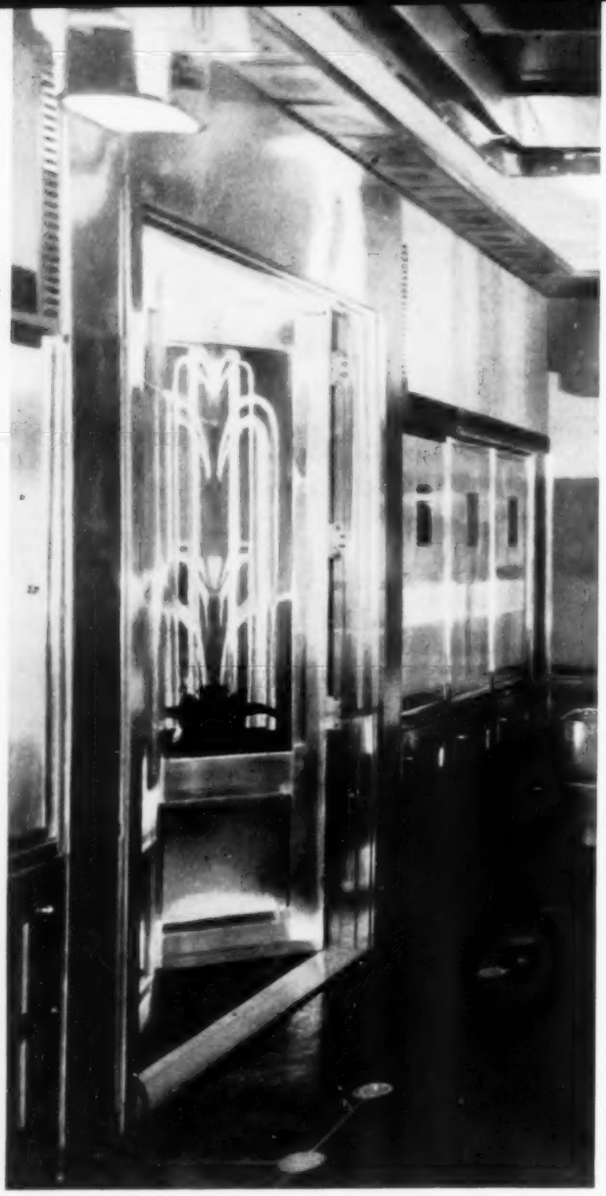
MUCH that has been said regarding heat and corrosion resisting castings in that section of this magazine starting on page 51 has corresponding inferences in the rolled and wrought stainless steels. Practically all of the analyses commonly used as castings are malleable when hot (or can be made so by minor changes in chemical composition) and consequently are available on demand in the form of plates, bars and shapes, and even sometimes as thin sheets.

A few new high chromium alloys have appeared beyond the main classifications listed in The Book of Stainless Steels. Perhaps the most interesting is an American adaptation of an alloy commonly used abroad, in the form of a high chromium iron containing a little nickel. We, in the United States, are very familiar with the low carbon 16 to 18% chromium steel which has given such satisfactory service in nitric acid plants. These steels are of ferritic microstructure — that is, the carbon is so low that nearly all of it is soluble in the ferrite, and hence there is no transformation into austenite at high temperature, and the metal cannot be hardened usefully on quenching. Some trouble has been had with this alloy from brittleness; close control of operations in the steel mill is necessary to prevent the cause, namely, grain growth of the ferrite microcrystals.

Addition of 8% nickel to such a ferritic alloy brings us to the well-known 18-8 variety which also is non-hardenable, but for the entirely different reason that the microstructure is now a stable austenite which does not transform during the usual heat treatments. An intermediate amount of nickel produces intermediate microstructures in which the austenite forming at high temperature will transform into martensite on cooling. Hence this alloy is hardenable.

The development of the 16% chromium, 1% nickel steel provides the aircraft designer with a material which, though not quite as corrosion resistant as the more expensive 18-8 variety, can be readily machined or otherwise fabricated and then heat treated. When properly hardened and tempered, this 16-1 steel has a proportional limit of over 100,000 psi., and an ultimate strength of at least 190,000 psi., with not less than 6% elongation in strips 0.015 in. thick or more. Izod impact tests reveal a toughness not noticeably lowered when subjected to temperatures as low as —40° F. Comparative figures for austenitic steels like 18-8 show that they also retain their toughness, even to liquid air temperatures, but would require very severe cold work to produce an ultimate strength equal to that above quoted. Likewise the straight 18% chromium, low carbon alloy has little ductility when hardened by cold work to ultimate strengths of about 110,000 psi.

The two alloys, 18% chromium and 18% chromium, 8% nickel, continue to be the ones rolled in largest tonnage. As to 18-8, this most useful alloy has been made quite machinable by the addition of sulphur or selenium. It is also becoming more "stabilized" in the market by a better understanding of what takes place when heated metal is subjected to strong corrodents, knowledge that such circumstances are not at all universal and further by information on how to avoid trouble by selecting a properly fabricated



Stainless Steel for Architectural Trim, Either Outside or Inside, Has Unique Merits

alloy. There is still disagreement among various schools of metallurgists. Some insist that the best way to stabilize 18-8 austenite is to keep the carbon very low. Others believe that a definite program involving heat treatment, cold work, and alloying with titanium is quite as practicable. Still others point out the advantages of titanium or columbium as an element for stabilizing 18-8's containing medium low carbon.

As an example of the severe service now undertaken may be cited welded collector rings and exhaust manifolds for aircraft engines made of 18-8 steel sheet containing 0.08 max. carbon and stabilized with titanium. Hot gases carrying corrosive lead compounds heat these engine parts to at least 1500° F. without damage along the welds ("weld decay"). A curious fact about this particular job is that the sheet from which the parts were made did not stand the 100-hr. salt spray test or the boiling nitric acid test, both of which are frequently specified as acceptance tests for corrosion and heat resistance.

Data on specific installations in the various industries bring forth a continually growing mass of information on the performance of the different alloys in specific applications, but no general agreement can be reported as to the comparative value of 18-8 and 19-9 (say) for welding, deep drawing, and other fabricating operations, stability of the austenite, and tensile and fatigue properties. However, much so-called 18-8 is now made with combined chromium and nickel over 28, rather than 26%; the higher alloy is more stable under severe corrosion at atmospheric temperatures.

In installations in paper mills, as tubing, linings, digestors, receivers, and the circulating systems handling sulphite liquors, some very satisfactory service has been given by 18-8 sheet and plate containing 3% molybdenum. Users report that this alloy has small tendency to deep pitting; for some reason concentration cells existing under small particles of attached foreign matter do not form and eat into the metal by "contact corrosion." The chemical industry has also taken considerable tonnages of this same alloy for uses best known to itself.

The high molybdenum alloy (higher than formerly recommended) is also excellent for dye vats handling woolen textiles. Many of these dyes contain up to 1% of organic acids, like acetic and formic, and are heated to about 175° F., where they attack nearly all metals sufficiently to spoil the color.

This alloy has received a great deal of attention by the manufacturers because of difficulties in handling. It is necessary to watch the analysis very closely, as well as the melting conditions, mold size and shape, heating for forging or rolling, and the drafting in blooming mill or forging press.

Those steel mills which have established themselves in the stainless industry have generally improved their equipment and methods for the more economical production of material rigidly inspected for shape, size, and surface condition.

Acceptance standards are being constantly raised, thus continuing to present new handling problems to the manufacturer, which means a continual change in methods. Therefore, these products will receive a great deal of attention by the steel maker. This means the development of special equipment, and of especially skilled crews devoted solely to the production of these alloys. Plates of $\frac{3}{16}$ in. or $\frac{1}{4}$ in. thick and up are available in any size nearly up to the limits for alloy steel; angles or structural shapes capable of being rolled on an 18-in. mill are also on the market. Special bar sections, either hot rolled

or cold drawn, are available in almost unlimited variety. Welded pipe and tubing of low carbon 18-8, with or without molybdenum or "stabilization," has recently appeared on the market, in competition with the seamless variety available for the last 8 or 10 years.

Two varieties of stainless-clad sheet and plate are being vigorously promoted with a view of entering uses where the cost of solid metal has so far been a handicap. Logically, it would seem that continuous coating of really resistant metal 0.02 to 0.03 in. thick would be all that is necessary to protect a base metal tank, say, from the contents and vice versa. Composite sheets have been successfully made by heating slabs of stainless and mild steel with a ductile intermediate layer of pure iron in a reducing atmosphere, welding them in a heavy press, and then proceeding to roll them out as desired. Another method starts with a composite faggot of carbon and stainless steel slabs, edge welded to exclude oxidizing gases during heating and rolling.

Fabrication is done by butt-welded joints, welding through from the rear with steel welding rod, then cutting out a V on the stainless side and filling this with appropriate welding rod.

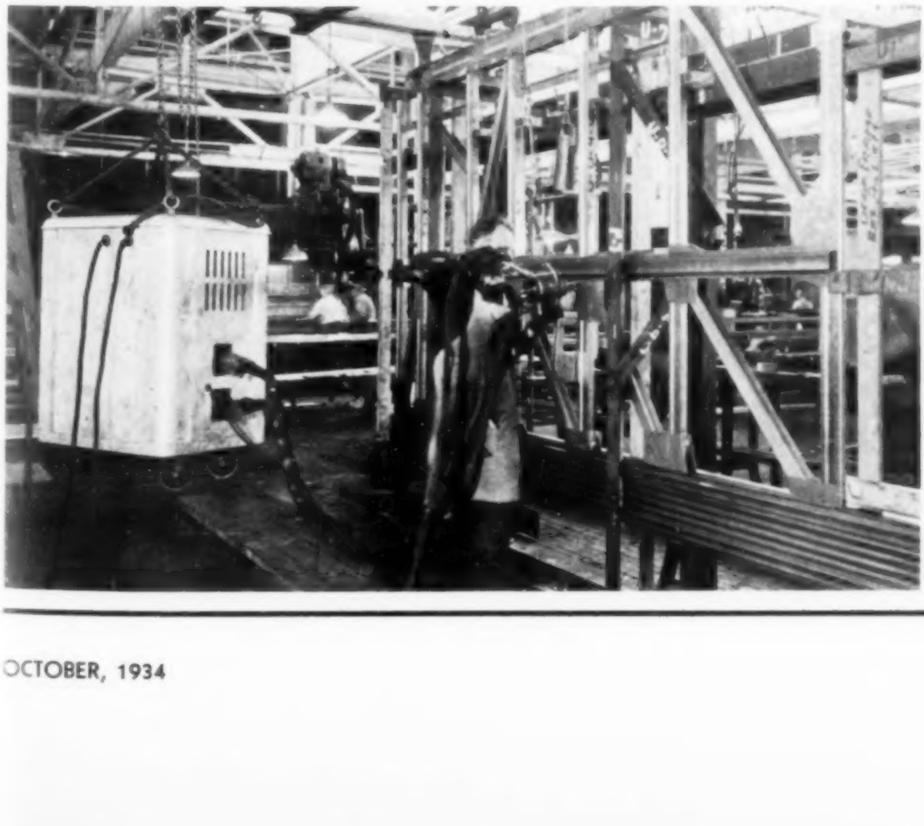
Outlets Into Consumption

After a decade or so of intensive development of the chromium-nickel steels, therefore, the situation has now resolved itself into one where most of the new things talked about are changes in the old consuming markets and entrances into new ones.

Producers of the stainless alloys, like those of the bright non-ferrous alloys, find that whereas before 1929 the so-called "luxury" demand appeared to be the most important, during the depression years the "utility" demand is keeping the market alive. For instance, a lot used to be said about decorative uses in architecture and for interior trim; this market is now dormant, but such a seemingly minor item as a burner for range oil has absorbed an astonishing tonnage of high chromium sheet. Naval vessels use much stainless for such things as masts, ventilators, deck houses, water-tight hatches, doors and cables, where a minimum of weight, resistance to corrosion, and non-magnetism is desirable.

High speed rail transportation is common talk among engineers in this year of 1934, and it is pleasant to record that no less a personage than Ralph Budd, president of the Burlington Lines, says that the "experiment" with high speed passenger traffic is not a mechanical experiment but solely an experiment with the traveling habits of the American people, for the Burlington Zephyr (a stainless steel train) has traveled 15,000 miles with but three unimportant mechanical troubles, once hitting a truck at 40 miles per hr. without serious damage to the train. He goes on to say what every metallurgist knows, that such a train could not have been built without advanced metallurgy as typified by 18-8 sheet, shot welding, cromansil welded frames, roller bearings, a light weight 2-cycle diesel engine and crumpled aluminum insulation.

A recently delivered 5-car articulated train for the New York Rapid Transit Corp. indicates another outlet for light weight cars — designed to speed up local service and increase its capacity without reinforcing the 50-year old elevated structures. By using built-up sections of cold worked stainless steel strip, the weight has been reduced to 80 tons, less than half that of a conventional



Joining Structural Members of Stainless Steel in Frame of Elevated Cars by a Type of Spot Welding Where the Time is Limited so That the External Surfaces Are Not Heated Above Temperature for Carbide Precipitation (Courtesy Edward G. Budd Manufacturing Company)

train of equal passenger capacity. The strip is cold rolled to high strength (values are around 150,000 psi.) and there is still sufficient ductility for forming operations.

Automotive Uses

In 1930 the stainless steel industry got a great boost when the Ford Motor Co. used it for radiator shells, lamps, and hub caps. In 1931 the most important parts in that car of stainless steel were lamps. Since then the use has shrunk to beads around radiator grilles and various moldings and trim, but the hub caps have grown a great deal and now comprise the major use.

A survey made during the summer by Metal Progress of the entire automotive industry shows similar trends. Chromium plating technique has progressed so rapidly that many bright parts can now be plated over brass to the industry's standards of perfection and durability. (Whether these standards are high enough, in view of the generous use of salt on wintry roads, is another question!) Consequently the large use which still exists for stainless strip for beading and molding indicates an over-all fabricating economy by using the more costly metal. Stainless strip can be furnished in any gage and width, and with surface conditions which polish very quickly in the customer's plant.

Any factor of comparative durability of one bright metal surface over another is now given second place to the designer's wish to decorate the body according to current styles. The trend in 1934 bodies was definitely away from large surfaces of bright metal, for which stainless steel sheet is unapproachable. Beads, trim, moldings, and window runs and other door hardware remain as the quantity use — even as little as a couple of pounds per car mounts into daily tonnage in the American industry. Stainless metal beads offer a very convenient and successful method of accent and relief; fine lines of mirror-bright metal are always in the best of taste against almost any body color.

As an indication of the economy urge, hub caps, which now constitute the largest area of bright work on most cars, are frequently made of very thin stainless sheet, embossed and lacquered with the insignia and then curled over the edges of a thicker mild steel backing.

Practice differs in the use of stainless for such corrosion resisting parts as pump shafts; many makers believe that nitrided or hardened alloy steels will give adequate service. Some minor uses for exposed bolts, pins, and nuts continue, as well as for shutter and heat control valves and parts about the fuel system.

An important outlet for stainless steel sheet is into the various food processing and vending industries. Milk and milk products, preservers, cookers, dryers and refrigerating equipment, as well as the brewing industry, find places where the material more than earns its way. Corrosion resisting properties of this group of steels have caused it to be used to a considerable extent in newly opened breweries, and for the inner shell of beer barrels. Coca-cola barrels are now also being made in production quantities from 18-8 with 0.07% max. carbon.

Hotel and institution kitchens, diner and ships' galleys, cafeterias, soda fountains and liquor bars utilize it because it is unstained or unattacked by all sorts of food stuffs and beverages. Outdoor sign frames and such minor decorative construction, which will remain attractive though neglected by cleaners, is an interesting possibility just beginning to be realized.

To these uses, where brilliant appearance, retained at temperature up to boiling water, must be added those more utilitarian uses in the chemical and process industries where resistance to attack at higher temperatures is more important than an unsullied polish. For instance, a large installation of 12 to 14% chromium steel (the turbine blade analysis) is contemplated as seamless tubes for high pressure steam boilers. Chromium steel tubes containing over 20% chromium have been installed in waste heat recuperators, as soot blowers and in power plants as high temperature superheaters.

In a recent address, Dr. F. M. Becket also called attention to a new use for steels containing 25% chromium and 15% nickel, in the form of singe rolls for cotton cloth which operate at 1400 to 1700° F. and burn lint from the cloth's surface.

The oil industry has a very large amount of money invested in the chromium alloys of the "stainless" varieties. Steels with nickel and chromium, each of 20% and more, have given excellent service in the hydrogenation of oils under high pressures and at elevated temperatures. The widespread interest in the hydrogenation of petroleum warrants mention that operating practice has recently reached a pressure of 3600 psi. and temperatures between 750 and 1100° F. It is safe to say that commercial operation under such severe conditions is dependent on steels having great strength at elevated temperatures and an adequate resistance to flame oxidation.

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IN CIRCLE · ENLARGED OVER THREE TIMES
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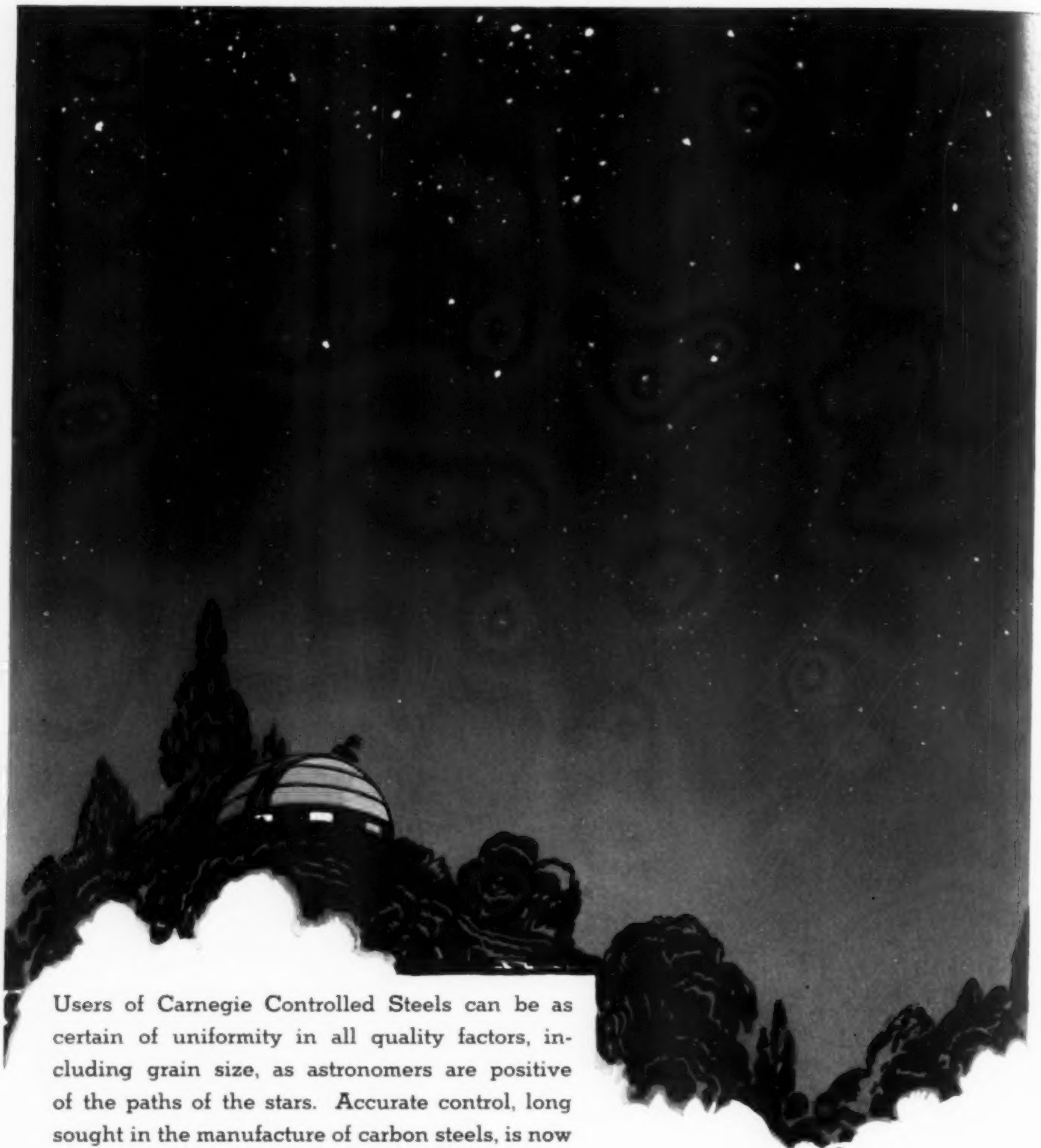
STEELS

SHEET, STRIP and COLD DRAWN STEELS — CARBON STEELS . .

● Any review of progress in carbon steels in post-depression years must pay attention to three noteworthy developments — first, the production of steels with controlled grain size, either low carbon carburizing grades, medium hard machinery grades, or high carbon tool materials; second, improvements in hot rolled and cold drawn rods for screw stock and cold heading; and third, better strip and deep drawing sheet steels. . . . ●



CARBON STEELS FOR BARS, RODS, SHEET AND STRIP

IT IS superfluous to dwell upon the work leading up to the present interest in grain size of carbon steels. Members of the American Society for Metals have been prominently identified with it, and the Society's publications have carried the majority of the informative articles on the subject. If this point need be proven, proof can be had from the authorities cited in the brochure recently issued by one of the largest steel companies concerning its steels of controlled grain size, wherein 11 of them were in METAL PROGRESS, 13 were in *Transactions*, and 14 in all other publications combined.

So it is unnecessary to dwell long upon the subject of grain size before an audience such as the readers of this article. Manufacturers of machine parts had only to segregate heats of steel from their receipt through all forging, heat treating, and machining operations, to find that there were pronounced differences in costs of production and properties of finished pieces which could not be accounted for by differences in the routine chemical analysis. Grain size, as determined by the McQuaid-Ehn carburizing test, seemed to be one important controlling factor, and this has been put into the purchase specifications and accepted by most steel makers.

Even those who are still doubtful whether this includes all the elusive characteristics of a quality product must admit that grain size control represents a distinct improvement in plant metallurgy. Research men may eventually discover the correlation between machinability, forgeability, hardenability, or toughness, but so far the known relationships are empirical and have been found by trial and error. In general, the fine-grained steels are distinctly tougher (as might be expected) and perform better in the forge shop. Coarse-grained steels are more machinable and harden more deeply.

Production of steels of controlled grain size, in either electric or open-hearth furnaces, has caused intent study of melting and casting practice. (In passing, it may be remarked that it was quite a task to fix the source of variations in grain size definitely in the steel making plant rather than in the heat treating department.) Success involves accurate metallurgical control in all phases of the process, better trained workmen, more attention to the slag characteristics, rapid methods of analysis of both steel and slag, accurate observation and recording of all ordinary operations as well as unusual happenings. "Metallurgical observers" in the tonnage steel plant and rolling mill date back at least seven years, and in this time a body of experience has been acquired which enables the producer to reproduce successful results fairly well.

While steel makers have so far been reticent as to the exact methods in use, it is usually as-

sumed that fine grain in steel is due to the presence of a cloud of non-metallic particles which act as nuclei of crystallization, and that one way to get the effect is to tap the heat when it still has a small amount of iron oxide in solution, and deoxidize in the ladle with aluminum.

This is still a fertile field for investigation, because occasional heats do not turn out as expected, either producing a fine or mixed coarse and fine grain when coarse grain is desired, and vice versa, and there are sometimes variations ingot to ingot. In the carbon steels grain size is of especial importance to the medium-high carbon ranges, say from 0.30 to 0.60%. Fine-grained steels in this range can be heat treated to properties and toughness so good that they are encroaching on the field formerly occupied by alloy steels. It is probable that when the effect of manganese and silicon is more carefully studied, this general all-around excellence of carbon steels will be further increased. Hardenability becomes an important property in these steels, and tests for this property as well as forgeability are being made to appraise the heat during manufacture and before shipment.

More Accurate Rods

Other elements of mill practice have also had attention. With the adoption of helical springs for front end wheel suspensions on automobiles came a demand for steel rounds in large tonnages free from surface scratches and of close tolerance as to size. This at first required cold drawn bars, or rods which had been through a surface grinder. Now it can be done by hot rolling the rod in accurate, closely adjusted mills, from a descaled bar finished at the correct temperature. Tolerances accepted have been as low as 0.001 in. and approach the limits set for cold drawing.

Where the cold drawing industry will always have the advantage is in producing relatively small lots of special shapes by drawing through dies, much more cheaply prepared than special rolls. Trend in the cold drawing industry is also to draw to definite physical properties (and to heat treat the entire order if necessary) so that the material will suit the customer's needs and be quite machinable even when possessing tensiles as high as 125,000 psi. Magnetic inspection of an entire shipment to assure freedom from surface defects is also available at several mills.

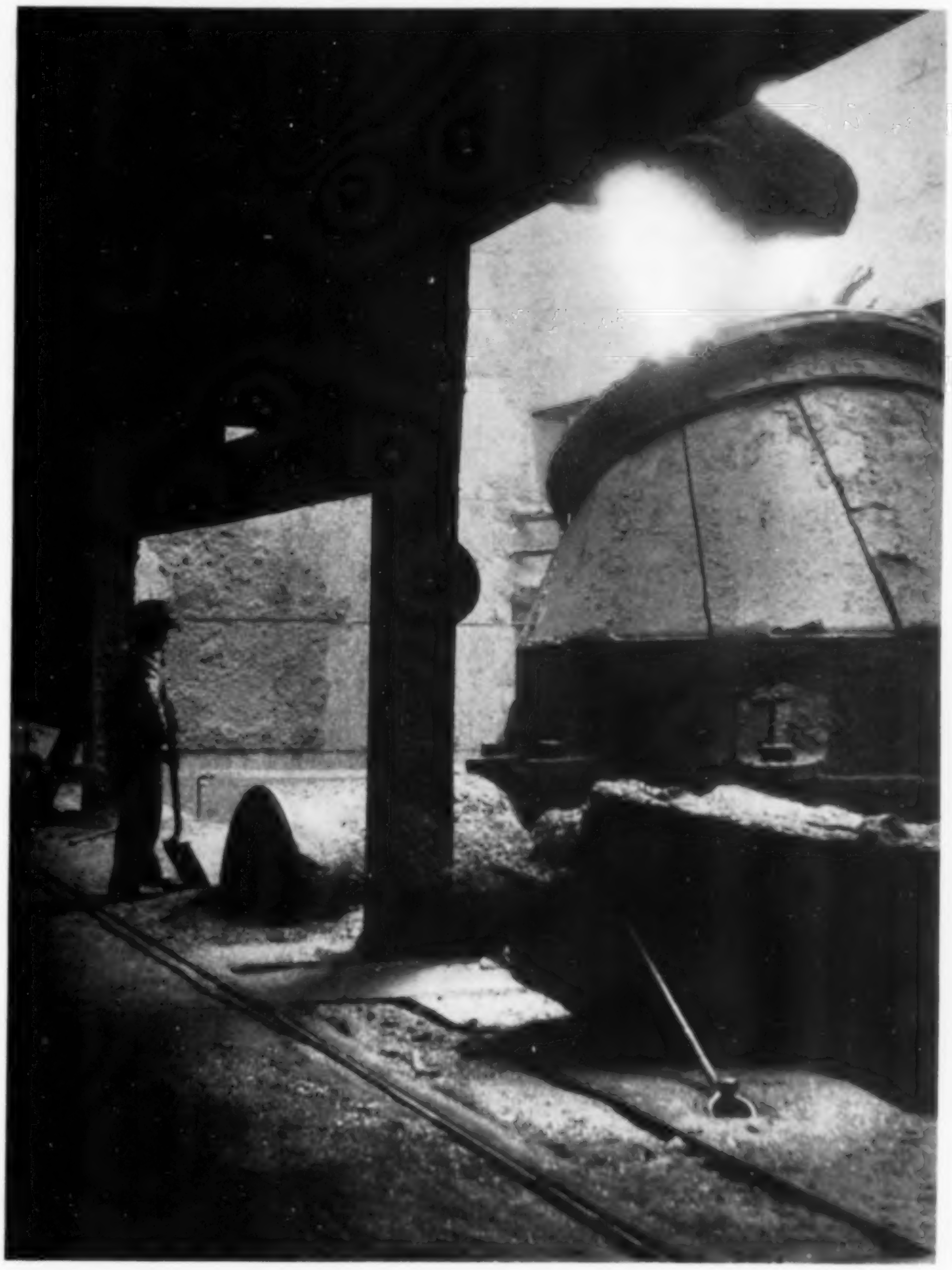
It should not be supposed that the harder grades of carbon steel have been monopolizing attention, for as much, if not more, has been done on the softer varieties, either rolled and cold drawn for heading and screw machine work, or in the form of sheets. Important changes in plant practice and new equipment have revolutionized both the cold drawing and the sheet industry since the war. Even the somewhat discredited bessemer process has been intently studied, with the result that its product has been improved and definitely shown to have a marked individuality suiting it for definite engineering purposes.

H. W. Graham has told this story before several chapters of the American Society for Metals in a discussion of machinability of screw stock, a 15-year investigation which had negative results as far as developing a test for machinability, but one which shed much light on the metallurgy of the steel manufacturing processes. The ideal steel for machinability is one which is soft and brittle, and yet does not work harden during rapid shearing under compressive loads (that is to say, cutting). High sulphur bessemer steel is soft and brittle, but does work harden, and to wide degrees, heat to heat.

For instance, if the work hardenability is measured by change in impact and hardness after 6% reduction by cold drawing, one heat (rather insensitive to work hardening) might lose one-third its toughness and gain 25 points in Brinell hardness. An average heat might lose half its impact value and gain 35 points in hardness, whereas in an unusually sensitive heat the toughness might fall to 5% its original value and the hardness increase 60 Brinell numbers. These "sensitive" heats also are the ones which age harden.

While the cause of this variation in sensitivity is unknown, it seems to date back to the raw material; one guess is that it is related to colloidal compounds of oxygen and nitrogen. While coarse grain will enhance the machinability, it is not the whole story. At any rate, the characteristics of bessemer steels can now be determined before final rolling, drawing, and shipment, and the customer can be assured of metal selected to meet his particular requirements and not produced by happy-go-lucky methods. Machinability, as measured by tool life in a screw machine, has improved materially—even as much as 100% in extreme cases—by close control of steel making operations, without changing the chemical composition. (Extra machinability has also been provided by a higher sulphur steel containing more inclusions, without

Careful Studies of the Properties of Bessemer Steel Indicate That the Material and Process Have Unexpected Potentialities (Photo by John Goski)



it is said, harming the tensile, torsion, and transverse impact values.)

Before the subject of bessemer steel is passed, some mention of phosphorus in steel should be made — that element which really is responsible for the decadence of the bessemer process in America. Everyone has heard the statement that phosphorus is a bad embrittler; however, one of the recently promoted high strength structural steels has 0.10 to 0.20% of phosphorus put into it. Furthermore, the bessemer process itself may have some intrinsic merit, for a statistical study of the basic converter vs. basic open-hearth steels shows that when tensile strength is equal, the ductility of the converter product is measurably better.

Requirements of steel for cold heading have also been carefully studied by both steel producer and consumer. As shown in Mr. Graham's article in Metal Progress for August, 1933, this is usually made of rimming open-hearth steel, and therefore entirely different in origin from the above. The ingot has a surface of purer metal than the cores, and therefore produces wire having a softer and more plastic surface.

Up to a few years ago, bolt makers specified low carbon steels (0.06 to 0.12%) but more recently it has been found that higher carbon steels can also be used without undue wear on the dies if, during its manufacture, the rod is heated above the critical for grain growth. The proper coating, of grease, soap, rust and lime ("sull-coat") and even glossy lacquers, are of importance in this connection.

The work done on the rod by the cold heading machine causes a certain amount of hardening and embrittling, and brings in considerations similar to those briefly mentioned above as to "sensitivity" of the steel. Some measure of control can now be exercised over the embrittlement, but as yet nothing much can be done about the associated hardening.

In those operations where cold headed articles must be machined (as the cutting of threads on bolts) two sets of opposing requirements are

met. For best cold heading the steel must be soft and plastic; for best machining, soft and brittle. Pity the poor metallurgist!

Sheet and Strip

Development of continuous sheet mills has been the outstanding mechanical achievement of the steel industry since the War. Strip mills have also been widened and made more accurate until there is only an arbitrary demarcation between sheet and strip as far as width is concerned. Rapid production and unusual properties have come about in strip practice by mills which combine tension and rolling to a degree that approximates drawing through an adjustable rolling die.

Consumers were primarily interested in the cold drawing properties of these thin metals — a property as elusive as hardenability and machinability. However, the steel mills have been able by various means to furnish sheets of unblemished surface, properly normalized, which will stand more and deeper work in stamping and drawing. As this became an undoubted achievement, purchasers asked for and have been getting bigger and better sheets until an automobile body from a single one does not seem beyond the future possibilities.

Drawing quality, as it may be modified by the manufacture of low carbon steels, was clearly discussed by Thomas Dockray before the 1931 convention in Boston. Up to ten years ago the best idea of a sheet's performance, short of actual trial in a given die, was derived from a study of the percentage elongation in a tension test piece cut from the sheet in directions both parallel and transverse to the direction of rolling. At that time steel metallurgists depended on Rockwell hardness test, chemical composition, and flat bend to judge the excellence of the product.

This whole matter has been seriously complicated by the habit which some mild steels have of changing in hardness and ductility between the time they are tested and approved for shipment, and when they actually arrive at the forming press. This "aging" phenomenon is thought to be some form of precipitation hardening, and is variously ascribed to carbon, iron oxide, nitrogen, and oxygen, originally in solution in ductile ferrite, but slowly precipitating out with time (or rapidly as the sheet is cold worked) thus hardening and embrittling the metal. The situation is complicated by the fact that not all steels are equally at fault in this respect, while others which seemed rather hard by Rockwell hardness and tension tests gave no trouble in the dies.

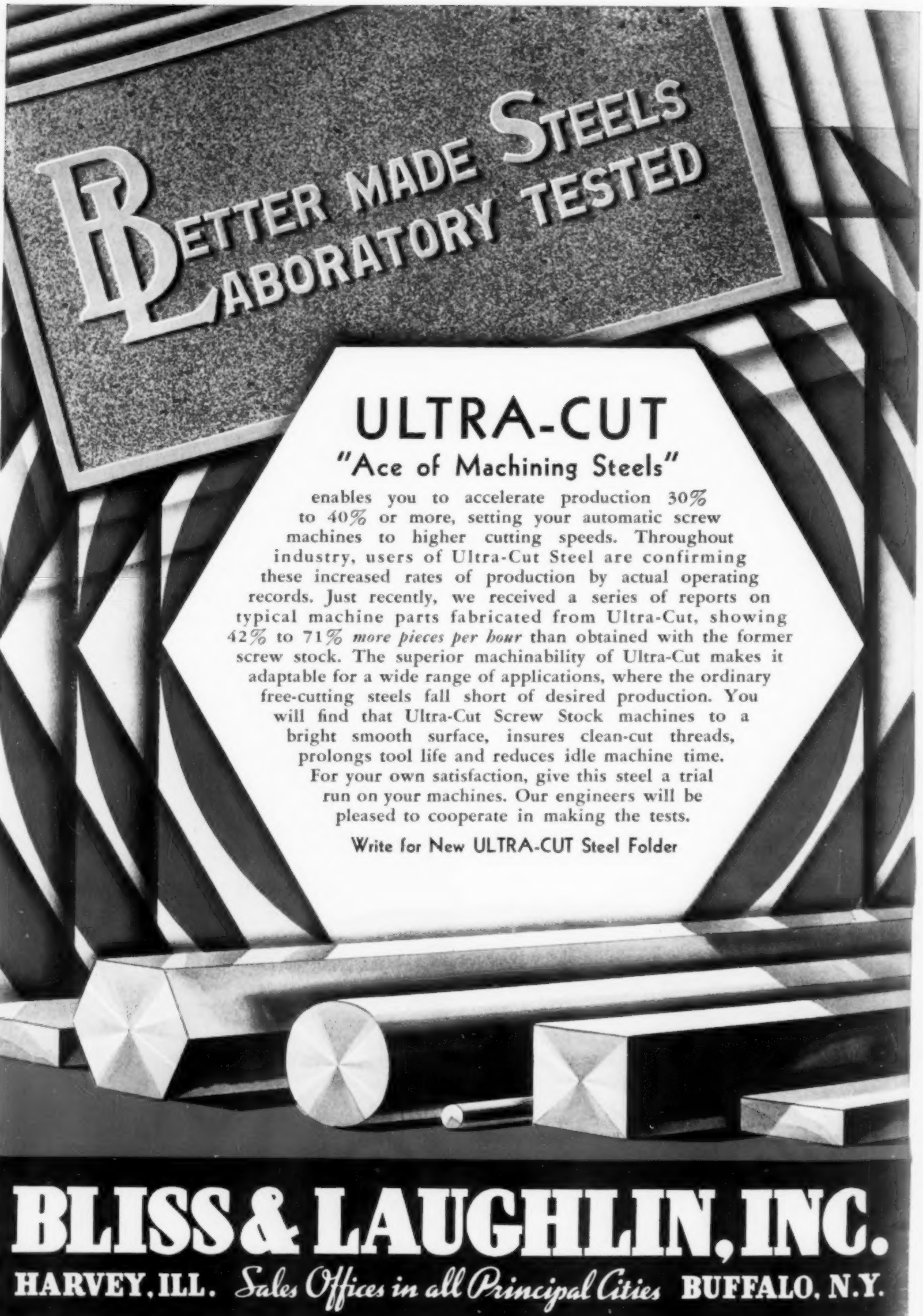
Acting on the general assumption that mild steel is most plastic immediately after a moderate amount of overwork, it became common practice immediately before extra severe drawing to pass the sheet through a roller straightener, thus bending the sheet sharply back and forth several times. In this condition the steel can be deformed at a faster rate without premature fracture taking place, and without formation of "stretcher strains."

Stretcher strains are lines of depressions or elevations which destroy the evenness of the surface; when the markings are extensive it is necessary to grind and polish the surface of the stamping, or else scrap it. Joseph Winlock and G. L. Kelley showed that these markings are due to fluctuations occurring at the yield point. They are associated with steels having a definite "drop of beam" during tension tests. In others where the transition from elastic to plastic behavior is gradual — so that no definite yield point can be determined on the stress-strain curve — stretcher strains will not occur.

Non-Aging Steel

The problem of making steel free from the strain-aging effect has been attacked both in steel company laboratories and by the cooperative investigation in Pittsburgh. One producer has advertised a "stabilized" steel for deep drawing purposes, but no information as to method of manufacture has been made public. A criterion is said to be the strength at 400° F. (in the "blue brittle" range) — if this is no greater than at room temperature, the strength and ductility of sheet, cold rolled 2%, will be practically stable against changes due to aging.

Ferro-carbon-titanium has had extensive use as a mild deoxidizer and scavenger to improve the rimming of ingots for sheet steel. Low carbon alloy has also been available for steel with carbon held to 0.06% or lower, as required by some users of deep drawing stock. In the Pittsburgh investigation it was shown that the method of deoxidation had an important influence, because it was found that commercial heats of rimmed, semi-killed and silicon-killed steels are very susceptible to strain aging. On the other hand aluminum-killed steels strain age considerably less, and a steel deoxidized with silico-manganese in the furnace and killed with aluminum in the ladle was reported as "essentially non-aging."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$1\frac{1}{4}$ MINUTES about the WELL-KNOWN ATMOSPHERE

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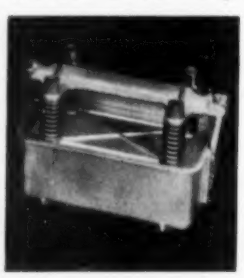
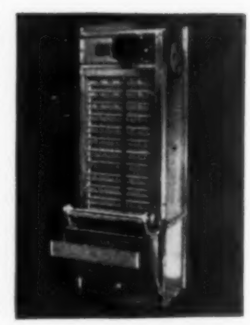
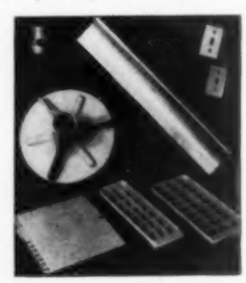


Aluminum's natural resistance to such corrosion can be immeasurably enhanced by economical surface treatments that should never need renewal.



People want to know these days how long their purchase is going to last. Whether your product is going to be used outside or inside, "exposed" or "protected", the atmosphere gets to it . . . and it has as little effect as possible when you specify Alcoa Aluminum. Some one of the many Alcoa Aluminum Alloys will have the right physical characteristics for your job. Let us help you select it. Aluminum Company of America, 1801 Gulf Building, Pittsburgh.



[●There is nothing elsewhere in this advertisement to remind you that Alcoa Aluminum has the tensile strength of structural steel, with ⅓ the weight.]

ALCOA · ALUMINUM

IMPORTANT METALS OTHER THAN IRON

Of THE PRINCIPAL non-ferrous metals, aluminum takes first rank in interest because of its spectacular rise in half a century from a rarity to tonnage surpassed only by iron, copper, lead, and zinc. It might be recalled that Napoleon III used an aluminum table service when entertaining regal guests. Now the amount of this metal going into kitchen equipment is second only to that absorbed by all the transportation industries.

Such a rapid growth could have come about only by close study of the possibilities of the metal, by the discovery of new alloys and fabrication processes for special uses, and by reason of intelligent marketing. These things interest engineers and technicians, and so there have been no less than 44 articles printed in Metal Progress on new aluminum alloys and new uses. In itself this is a measure of the activity in that industry.

Automobile manufacturers buy nothing today if a satisfactory substitute can be had cheaper. Hence the volume of aluminum going into automobile engines for pistons and cylinder heads indicates that the metal has wholly unusual properties under heat and stress. However, such uses are rather prosaic as compared with the well-advertised applications to high speed rail transportation. Much aluminum has been in use for at least ten years in electrified suburban service, where the saving in weight has paid for itself many times in power and quickened schedules. Within the last year two really light-weight trains, using aluminum as the principal material of construction, have been completed, one for main-line and one for elevated service. Five similar trains will be delivered to Class I railroads this year, representing a capital cost of $2,000,000. Three are for the Union Pacific System and will be complete with diners and sleeping cars for long journeys. Two others (one for the Baltimore & Ohio, and the other for the New York, New Haven & Hartford) have coaches, parlor cars, and diners for daytime runs.

Aluminum in marine construction is not so well-known; L. H. Fawcett's article in Metal Progress for April, 1931, may be consulted for data. Of more timely interest (although of minor commercial importance) are the racing yachts which have just competed for the America's cup. One of the principal innovations in yacht design carried over from the Enterprise of 1930 to the yachts of 1934 is the duralumin mast, weighing in the Enterprise only 4200 lb. as compared with the 6000-lb. wooden mast of the Shamrock. This saves weight where weight

is to be avoided, namely, aloft, and hence increases the stability of the boat and enables her to carry more sail in a stiff breeze without heeling over too far and pounding into the seas. The mast for this year's cup defender, Rainbow, is higher and heavier, being 154 ft. from step to truck, and weighing 5700 lb. Cross-section is pear-shaped, maximum depth is 30 in., and width 18 in. Sheet metal at the base is about $\frac{3}{8}$ in. thick, at the top about $\frac{3}{16}$ in.

One of the early uses for aluminum was for high voltage electric lines. For this purpose a steel reinforced cable is favored by most American engineers; about 400,000 miles of it are now in use in this country.

The fields of architecture and interior decoration are two of the newer fields of application. Lightness is a matter of importance in the erecting of big spandrels but the metal is used on exteriors principally because it resists atmospheric corrosion and does not stain adjoining materials by drip. For interior work aluminum is permanent of color and easy of fabrication; many good examples of its possibilities are seen in the ticket windows, grilles, lighting fixtures, railings, gates and doors, windows and trim at the new Union Station in Cincinnati.

This Room, Designed by H. M. Schwartz, Is Walled With Bright and Colored Aluminum Sheet; the Inner Curtains Are a Woven Lace of Meshed Aluminum Segments

Architectural uses have been promoted by applying a surface treatment borrowed from the aeronautic field wherein the metal is oxidized in an electrolytic tank. This "anodic" treatment produces a corrosion and abrasion resisting surface which can also be impregnated with various coloring matters. This has naturally opened up many new possibilities for interior decoration, for packages and for art objects.

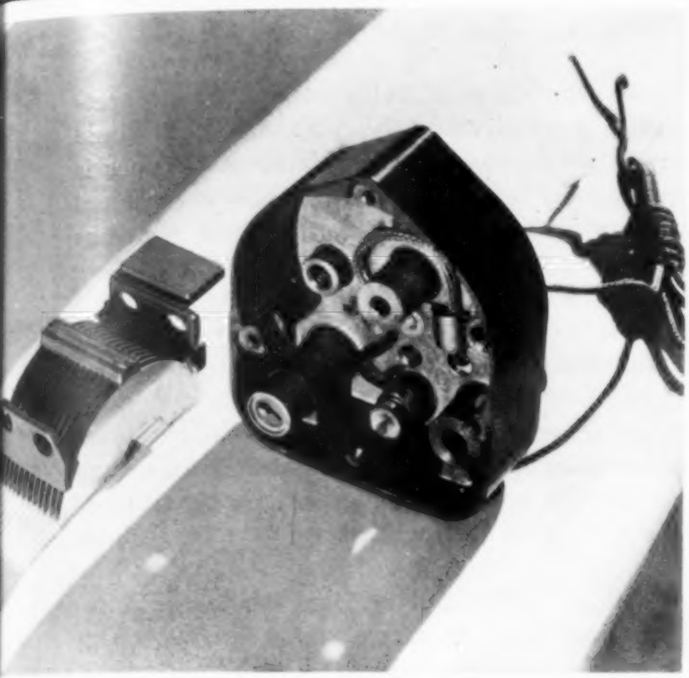
Aluminum foil is another product which has been utilized widely. To the more conventional uses of food wrappings may now be added bottle caps and tamper-proof closures for drugs, milk and liquors. Crumpled aluminum foil is also an excellent light-weight insulator; an even more efficient insulation is made of foil neatly cut and built into a honeycomb of small cubical boxes.

It goes without saying that these expanding uses — only a few of which can even be mentioned — have been backed by an intent study of the metal and improvement of its alloys, whether sand castings, die or permanent mold castings, sheet and foil, plates, shapes, tubing, forgings, extruded products, and even powder. Truly a most versatile metal!

Magnesium For Weight Savers

Magnesium is a metal closely allied to aluminum in many ways. It is also of special interest to members of the American Society for Metals because it has been made in commercial amounts in quite recent years, and because its uses are so widespread. Backed by intensive metallurgical study, the snowball effect of accumulated experience with successful applications is clearly noticeable.

An absorbing article by J. A. Gann in the April, 1932, issue may be reread for a story about the discovery of the reduction process — absorbing because written by one who attended the birth of the commercial metal, so to speak. Discoveries then made at Midland, Mich., brought the price of the metal in 1917 sharply down to \$2 a pound; since that time the price has steadily decreased (with improved metallurgy and expanding volume) to about $\frac{1}{6}$ as much. At the present time, therefore, the high strength magnesium alloy castings are in the same price range as the high strength aluminum castings.



so well established that tentative A.S.T.M. specifications have been written. A series of strong magnesium alloys are on the market for structural shapes and plates and a definite shop practice for fabricating them has been worked out, and a large body of information is available on surface protection and coloring.

One feature of magnesium which has militated against some applications where appearance of exposed surface is of importance, is the fact that the bright white metal tarnishes to a dull gray. While not sightly this oxidized coat is durable and protective — that is to say, exposure to ordinary atmospheres has caused no measurable change in the physical and mechanical properties of the recommended alloys.

Very interesting chemical treatments have been devised to insure against damage in unusual atmospheres. For instance, rolled and

Above: Case for Remote Control on Auto Radio, a Zinc Die Casting; At Right: a Valve Body Die Cast in High Brass; Below are Cold Chisels, Scrapers, Screw Drivers, All of Hardened Copper

So far, the important applications have been for items where weight is a prime consideration. A unique instance, much publicized, is the spherical gondola constructed for the stratosphere flight — made of magnesium alloy sheet it was strong, oxygen-tight, and allowed the balloon to reach a theoretical ceiling 1500 ft. higher than any competitive design. More prosaic weight saving applications are for truck trailers such as those for carrying completed automobiles. Using the strong, magnesium alloys in plate and shape forms, a four-car transporter will weigh about 20% less than the corresponding design in aluminum and about 50% less than the steel and wood constuction. These closed trailers are favored for long distance transportation, and deliver the cars clean and unmarred by weather and road dirt.

Weight saving is an important matter for truck and bus operators. They must consider more than the initial price of their equipment. Low dead loads not only mean less fuel and tire expense and higher speeds, but also more pay load without violating numerous highway regulations. Other important weight saving applications include air craft castings, landing wheels and instruments, portable tool parts, and moving machinery parts, both rotating and reciprocating.

Space prevents this article from making anything more than a statement that the fruit of 15 years' intensive study of the metal and its alloys has developed a successful practice for sand foundry castings which can readily be transmitted to any intelligent nonferrous foundry organization. Die casting methods and alloys are

cast forms are passivated by thorough cleaning and then immersing for 20 min. in a boiling solution of sodium bichromate and phosphate, or about 3 min. in a solution of sodium bichromate and nitric acid. The latter produces a pearly to brassy color on smooth surfaces, and not only is a good corrosion resistor, but gives a good "tooth" for paints and other similar finishes.

Nickel and Its Alloys

Nickel is another metal which has been promoted with energy and intelligence. Its utility as an alloy for iron and steel should not overshadow its equal importance as an alloy with copper, with copper and zinc in brasses, and the metal itself, either pure or alloyed with about 13% chromium and 5% iron. The new radio tube industry also takes much pure nickel.

Monel metal, as is well known, is a natural alloy — that is to say, it is the result of smelting and refining certain of the copper-nickel ores. It contains about twice as much nickel as copper, and has found innumerable uses in the chemical, processing, and food industries. More recently several other copper-nickel alloys have been studied.

In one the proportions of nickel and copper are just about reversed, giving tensile properties a little lower than monel, although better ductility and higher hardness. Some good qualities are strength at high temperature, resistance to action of steam, and high machinability — all of which indicate its utility to power plant equipment, valve trim, and turbine parts. An allied composition, 80% copper, 20% nickel, has also been very satisfactory for marine condenser tubes (see Robert Worthington's article in this magazine for July, 1933).

Special monel metals have also become available. One contains about 3.75% silicon and is intended for places where castings should be heat treated to higher hardness, resistance to wear, and especially non-galling properties. Another forging monel contains about 3% of aluminum, and may be air hardened and tempered to 325 Brinell with no decrease in corrosion resistance to most liquids.

The high nickel alloy containing chromium was introduced in 1933, although others not very different had been used for several years. It has solved some troublesome corrosion problems in milk and food handling, especially in cooling equipment using brine, and in steam-jacketed kettles.

Permanent Mold Brass Castings

Two important developments in copper metallurgy have already been discussed at some length in other reviews in this issue. Copper is getting some belated study as an alloying element for iron and steel (see page 12) and what has already been found about it indicates its future utility to be as a strengthener, acting by an age hardening effect. (This is in addition to its well-established use as a promoter of resistance to atmospheric corrosion.)

A second development, of greater present importance, is the improvement in copper tubing brought about by bright annealing methods (see page 68). Thin-walled copper tubing is now competitive with brass and iron for many domestic and industrial services, since the introduction of methods for making a sweated or soldered joint into couplings and fittings. D. K. Crampton discussed this matter in the June issue.

Some new or modified alloys have been attracting interest. Silicon bronzes are being made in at least half a dozen slightly different analyses by various mills and have the same general desirable properties. Copper-nickel-aluminum alloys have remarkable corrosion resistance, and as a group have very interesting age hardening properties. Another alloy, which has, among other things, been put into non-sparking tools for metal workers, is the beryllium copper; it should (but won't) silence forever the twaddle about the lost art of hardening copper.

In the field of pure sheet metal, mention should be made of the commercial production of thin sheet (1 oz. per sq.ft.) by electrolytic methods, and the method of obtaining quickly a natural patina on copper. It is regrettable that more space cannot be devoted to these items in this review, for they will undoubtedly lead to many applications in the architectural field.

Paralleling developments in the die casting of zinc and aluminum has been the successful casting of copper alloys in permanent molds. Here a difficult problem has been the dies, pots and goosenecks which must withstand the extra temperature; lead could be cast by the ancients, zinc die casting is easy, dies for aluminum give considerable trouble, copper and iron alloys have been beyond the ability of most foundrymen to handle in fast-working permanent molds.

Success has finally been achieved by using separate melting pots, from which the brass, melting at about 1650° F., is ladled into a pressure chamber on the die casting machine. The

bottom of this chamber is a movable piston and an upward stroke forces the metal into the die cavity. One system uses metal in the mushy stage to avoid squirting out through the clearances between moving and stationary parts; in another system the liquid metal is held in the pressure chamber long enough for a chill to form and seal the clearance.

A very suitable alloy is the 60:40 brass, which has a low melting point. Its mushy range is increased by adding about 1% of lead; tin and a little aluminum are also of advantage. Pressure castings of this analysis have tensile strength of 45,000 to 50,000 psi. in ½-in. round bars — at least twice the strength specified by the A.S.T.M. for high brass sand castings.

Aluminum and silicon "bronzes" are also quite suitable for die castings. The former has been cast for several years by a method which sucks the metal by vacuum into a steel die through an opening immersed in the molten metal. This quiet flow deposits any of the troublesome aluminum oxide on the die surface rather than shooting it through the body of the casting. Such castings have been made up to 30 lb. in weight; tensile specimens cut from them will range up to 80,000 psi. tensile strength and 260 Brinell, depending on heat treatment.

Zinc Die Castings

Zinc has been the marvel of the metallurgical world in its approach to absolute purity. In War-time only the metal smelted from high grade ores of the Appalachian Mountains approached 99.90%. Electrolytic zinc, commercialized during that period, to handle the complex copper-lead-zinc-silver ores of the Rocky Mountain region, was able to equal this purity very readily. This seemed to be sufficient for all purposes until it was discovered (only a few years ago) that even higher purity would greatly improve the strength and stability of zinc base die castings. Now 99.99+ zinc is available for such purposes.

The story of these improved die castings has been told in METAL PROGRESS as the subject has developed. D. L. Colwell summarized the situation in last December's issue. When the analysis is right and impurities (principally lead, iron, and cadmium) held down to a total of 0.010%, the castings are nearly as strong as mild steel and somewhat stiffer, and change in dimension with age so slightly that it is detectable only by the most precise experimenter.

IF YOU NEED STRENGTH *and* CORROSION-RESISTANCE . . . .

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EVERDUR

Everdur Metal, a copper-rich alloy of the solid solution type, combines excellent corrosion-resistance with the strength of medium carbon steel. It is ductile...possesses high fatigue limit ...good machinability. It is non-magnetic and non-sparking. It may be cast, rolled, spun, stamped, forged and pressed...can be worked either hot or cold. And it is readily welded by all usual methods...Consider also its moderate price. No wonder Everdur has proved ideal for so many diversified uses.

Everdur is supplied in all commercial forms ...sheets, wire, rods, tubes, casting ingots, hot pressed parts and special shapes. It is being used for air conditioning equipment, grave vaults, hot water and process tanks, pole line hardware, springs and welding rods...to name but a few of many hundreds of uses. Seldom a week goes by but Everdur solves another metal problem.

EVERDUR METAL—"Everdur" is a registered trade-mark identifying products of The American Brass Company made from alloys of copper, silicon and other elements.

BERYLLIUM COPPER...

Annealed—Readily Workable
Heat Treated—Hard Enough to cut Steel

In the annealed state Beryllium Copper may be worked either hot or cold, and is readily rolled, drawn, stamped and forged. Subsequent heat treating of finished parts greatly increases tensile strength, fatigue limit and hardness. For instance:

A Beryllium Copper sheet, rolled 2 Nos. hard, showed *after heat treatment* a tensile strength of 200,000 p.s.i. and a Rockwell hardness of G-105.

And, a heat treated Beryllium Copper vibrator arm, vibrating at 230 cycles per second, showed no signs of fracture due to fatigue after two billion reversals—each of which involved a stress of 20,000 pounds. Temperature was varied between 100° and 300° F.

The use of Anaconda Beryllium Copper is spreading. Through it, many are realizing benefits previously unobtainable. Your request will bring further information without delay.

We are prepared to give definite heat treating suggestions for any contemplated use of Anaconda Beryllium Copper

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HEAT and CORROSION RESISTING CASTINGS • • •

● Alloy castings, high in chromium and nickel, are offered in such a bewildering number of analyses and trade names that a major job of simplification awaits the industry. This it has done for itself to the extent of recognizing 19 different classes. Some notes are here presented on high nickel, low chromium heat resistors and high chromium, low nickel corrosion resistors. ●

DEVELOPMENTS IN HEAT AND CORROSION RESISTING CASTINGS

ONE hesitates to venture very far into such a subject as heat and corrosion resisting castings because of its complexity. This — and the comparative youthfulness as far as the commercial production and application is concerned — makes certain portions of the subject highly controversial. It is certain that as more and more information is gathered and disseminated by both foundryman and user, most of the debatable questions will be answered, and the present bewildering array of compositions and trade names will be replaced by a few standardized alloys, whose reliability in particular services can be assured.

As in other branches of metallurgy, a brief historical account will be useful in appraising the present situation. For our purposes we need not go much further back than the War, for about that time the use of high chromium-iron alloys was suggested. True it is that nickel-chromium castings had been available some time before that (they had entered the market as a byproduct of the resistor wire industry) and they are still well established as economical high temperature castings when figured on the basis of cost per hour of service. Also we had high silicon cast irons for handling the mineral acids, as well as various non-ferrous metals and copper-base alloys, each applicable for certain anti-corrosive uses. However, the discovery that chromium was close to an all-purpose alloying element opened up an infinite number of possibilities, and without question has been responsible for the amazing developments in the last 15 years.

With many users and potential users studying the suitability of various chromium-nickel-iron combinations (with or without other alloying elements) and 50 or more producers, many trying to interest purchasers in trade named alloys for special applications, it is not to be wondered that the situation has been more or less muddled. The Book of Stainless Steels lists no less than 250 current chemical analyses of tarnish, corrosion and heat resisting alloys (and several times as many trade names!) and nearly all of them have been produced as castings.

Evidently, a major job has to be done in simplification. Some useful attempts in this direction have been made, one by the casting industry itself.

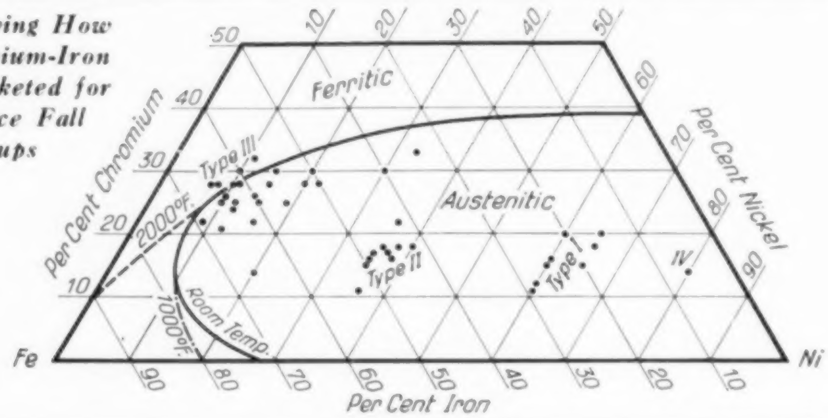
Another is by G. F. Geiger, of International Nickel Co., in his contribution to the Book of Stainless Steels, and applies to the chromium-nickel-iron alloys higher in alloy content than the 18-8's (and also is exclusive of the chromium-irons). It is:

Type I. 60 to 65 Ni, 10 to 20 Cr

Type II. High nickel, low chromium (35 to 40 Ni, 10 to 20 Cr)

Type III. Low nickel, high chromium (10 to 20 Ni, 20 to 30 Cr)

Diagram Showing How Nickel-Chromium-Iron Alloys Marketed for Heat Resistance Fall Into Four Groups



Type IV. 80 Ni and higher.

Types I, II, and IV also are used for corrosion resistance, but not to the same extent as type III, which may be subdivided into three parts:

Type III-*a*. Low nickel, high chromium (10 to 15 Ni, 20 to 30 Cr)

Type III-*b*. Equal alloy (20 to 25 Ni, 20 to 25 Cr)

Type III-*c*. High nickel, low chromium (20 Ni, 10 Cr).

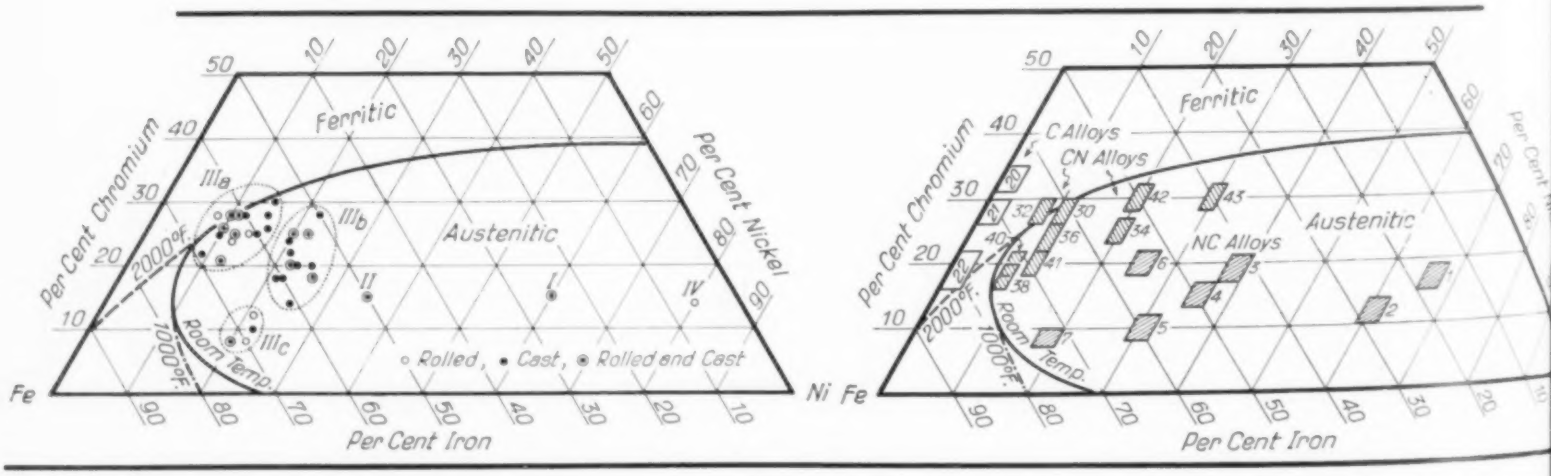
These areas are plotted on the accompanying diagrams.

The Code Authority for the Alloy Casting Industry has also segregated the commercial varieties, this time into 19 classes. Carbon content of the heat resistant castings is not specified except in one instance. The list is shown in the table on the next page, and the compositions are plotted on the ternary diagram just below.

This matter is of more importance than a casual consideration would indicate, for the most complex natural sciences (like botany and zoology) require a logical classification before much systematic study can be undertaken. It would be difficult, for instance, to make undoubted distinctions, other than first cost of alloying elements, between alloys NC-3 and NC-4 (both in Mr. Geiger's Class II) or between CN-38 and CN-40 (both in Mr. Geiger's Class III-*a*). However, it ought to be possible to distinguish clearly between Class II and Class III, and even between the three subdivisions of Class III. Later even III-*a* may be usefully subdivided according to whether the microstructure is ferritic or austenitic. Such classification also has the strictly practical object of giving an intelligible basis of specification by purchaser, and pricing by bidder.

As a matter of fact, there is ample evidence that this differentiation is being made by purchasers. The important interests in paper making, petroleum refining, nitric acid manufacture, and furnace building have pretty definite ideas about what they want and are able to see that they get it. Likewise careful buyers of so prosaic a thing as a carburizing box use accumulated experience as the basis of their expressed preferences.

Improvements in foundry practice are also



Geiger's Group III of Corrosion Resistant Castings May Be Subdivided Into Three Sub-Groups. Compare (at right) the regions marked off as commercial alloys by the Code Authority for the Alloy Casting Industry

noticeable. As in any new art, there has been an attempt to surround the practice with secrecy and to make much of the undoubted difficulty of making sound, high alloy castings. If all that were to be believed, one might wonder why so many castings were good! Intelligent control of all those foundry variables which make for efficiency, even in the gray iron foundry (namely, alloy composition, melting practice, pouring temperature, sand control, molding, coring and gating practice, final heat treatment and X-ray inspection), has enabled some new factors to enter the business and to turn out castings of constantly higher average quality. If and when the purchaser is assured of sound metal, it not only increases his confidence in the materials but enables him to reduce the factor of safety in the design, with accompanying economies. No better evidence of this is required than the success of cast carburizing boxes with thin walls, thin enough to compete as to heat transmission with those made of plate.

Centrifugally cast alloy tubes also represent a new development. It is not always possible to secure pierced tubing in the analyses most suitable for the particular application, and centrifugally cast tubing fills this need. Tubes represent one of the most difficult practical foundry problems when cast in the conventional manner; the centrifugal process assures an even wall section and dense, close grained material. The principal uses for such tubes are in heat treating and carburizing tubes, glass rolls, burner pipes, rolls for normalizing furnaces, gas cracking units, and furnace conveyor shafts.

Classification by Code Authority

Designation	Nickel	Chromium
Nickel-Chromium Alloys		
NC-1	65 to 68%	15 to 19%
NC-2	59 to 62	10 to 14
NC-3	37 to 40	17 to 21
NC-4	34 to 37	13 to 17
NC-5	29 to 32	8 to 12
NC-6	24 to 27	18 to 22
NC-7	17 to 20	7 to 10
Chromium Irons		
C-20	less than 3%	31 to 35
C-21	less than 3	26 to 30
C-22	less than 3	16 to 22
Chromium-Nickel Alloys		
CN-30	10 to 12%	26 to 30
CN-32	7 to 9	26 to 30
CN-34	19 to 21	23 to 27
CN-36	10 to 12	22 to 26
CN-38	7 to 9	16 to 20
CN-40	7 to 9	18 to 22
CN-41	10 to 12	18 to 22*
CN-42	19 to 21	28 to 32
CN-43	29 to 31	28 to 32

* Carbon over 0.15%

High Temperature Castings

Some general principles as to alloying chromium, nickel, iron and carbon for high temperature resistance have emerged.

Chromium is undoubtedly the metal for resisting oxidation and sulphidation; 15% is close to the minimum for moderate temperature, 30% is necessary for the highest. At high temperature creep resistance is low, but ductility is high. Silicon and aluminum both aid unmistakably in resisting hot oxygen.

Nickel converts the ferritic chromium-iron alloys into austenitic alloys, and adds strength and toughness both as cast and after long periods at elevated temperature.

Iron is useful for its strength, a fact that may be lost sight of when realizing that it is the cheapest metal of the three. Some metallurgists believe that additions of molybdenum and tungsten also help retain strength at heat. Carbon is a powerful strengthener, but tends to precipitate out of solid solution after long heatings in certain temperature ranges, and thus converts chromium-iron alloys, tough while hot, into brittle ones after cooling to room temperature.

Carbon is a useful foundry element for improving fluidity and castability, so the producer is anxious to have as much in the analysis as the service will stand. The purchaser, in the dark as to its real function and what the safe limit is, plays safe and insists that it be as low as possible, especially in corrosion resistant alloys. Such a situation breeds controversies!

Especially have the chromium-iron castings been improved by intelligent metallurgy. (This, of course, is not intended to say that the chromium-nickel alloys are not also being bettered.) Alloys containing 25 to 30% chromium resist oxidation indefinitely to temperatures just below their melting point. They are equally useful in high sulphur atmospheres, as in ore roasters.

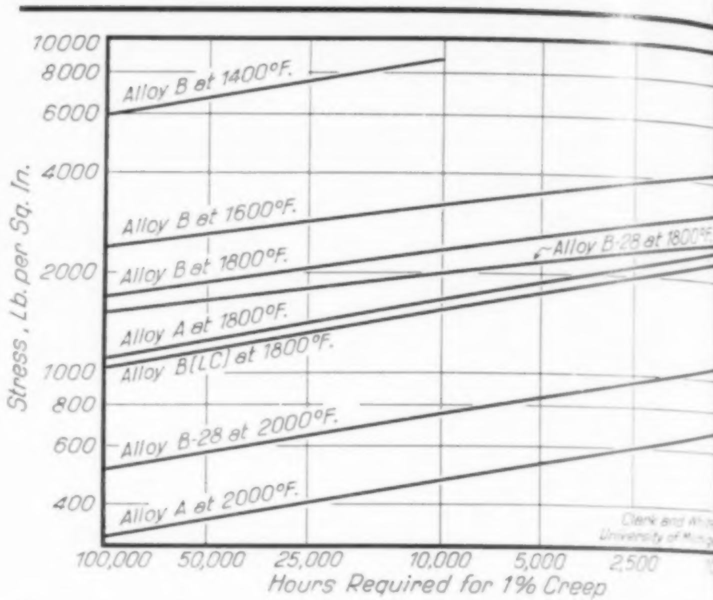
Unfortunately the Cr-Fe castings are coarse grained, and the alloy cannot be refined by heat treatment, being a ferritic one without transformation points. Work at the Union Carbide and Carbon Research Laboratories and its associates has found that if a high nitrogen ferrochrome is used in the melt, the grain size is much reduced and the strength, but especially the toughness, of the casting is increased. The nitrogen also retards the embrittlement which is noted in chromium-iron alloys after cooling to room temperature (even though they are tough at

heat). This embrittling action is also mitigated by a proper addition of titanium or columbium, which forms such a stable carbide that it might be regarded as withdrawing carbon from the system, converting it into an insoluble compound having no more effect than any other inclusion. A little nickel also helps toughen the alloy.

Furnace Parts

Furnace parts are of much interest to readers of Metal Progress; in fact, it may be said that an automatic continuous furnace of considerable size and tonnage depends upon heat resisting castings for its very existence.

Their success depends upon proper design as well as proper production, and design is difficult because the parts operate at temperatures where the metal becomes plastic under moderate loads, yet most engineering formulas are based on the assumption of elastic action. The engineer, therefore, must know as much as possible about the safe working strength of the metal; lacking that, the creep stress is useful — that which will cause 1% elongation in a definite number of hours.

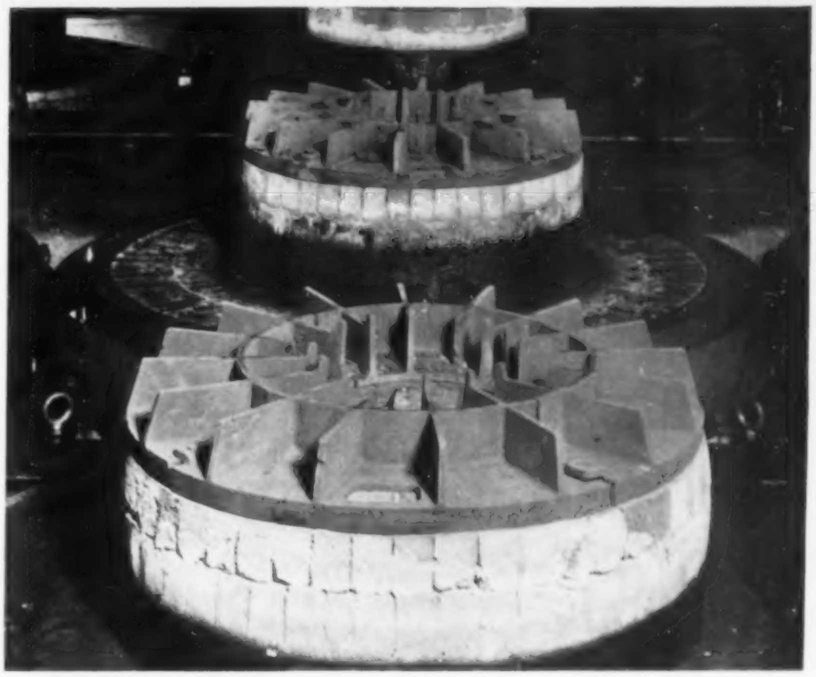


Relation Between Stress and Creep for Various Times. Alloy A is approximately 35% Ni, 15% Cr; Alloy B is high carbon 18% Cr, 8% Ni containing aluminum; Alloy B-28 is medium carbon 28% Cr, 10% Ni

Cast Alloy Pot With Walls 1/8-In. Thick

Such determinations as creep stress or time-yield relationships require a long time and accurate observations to establish, and are the more difficult as the temperature goes up. Nevertheless, alloy manufacturers recognize the necessity of this information, and one of them has sponsored work at the Department of Engineering Research, University of Michigan, which has produced the adjoining figure. Alloy *B* is a high carbon 18-8 containing aluminum; Alloy *B*-28 is a medium carbon 28-10. Both of these fall near the austenitic loop; the material difference under load at 1800° F. (especially of the low carbon Alloy *B*) is in line with a previous remark about the possibility of establishing undoubted differences within Mr. Geiger's Group III-*a* as to their essential austenitic or martensitic nature.

Alloy *A* is an austenitic alloy, approximately 35 Ni, 15 Cr, an analysis that is favored by furnace builders, and scientific data of this sort are sadly needed. All *published* figures on creep of nickel-chromium-iron alloys were assembled by L. J. Stanbery in *Metals & Alloys* last September, and for this particular alloy nothing was available beyond 1600° F. except estimates of "safe load" and "design strength." Extrapolating from a little data for lower temperatures, he drew a curve for design stresses for good quality material, really representing a guess at 1% creep in 10,000 hr. For 35-15 these figures scale as



Heat Resistant Castings in Base of Bright Annealing Furnace, to Carry a Pile of Coiled Strip Steel

follows: 1200° F., 3500 psi.; 1400° F., 1500; 1600° F., 650 psi.; 1800° F., 300; and 2000° F., 150 psi. Compared with figures now available for Alloy A, these seem to be hardly one-third as high as they might safely be, but the furnace designer is rightly cautious and uses a factor of safety to take care of differences in conditions likely to exist in a furnace operating for 20,000 hr., say, from a test sample in a laboratory, studied for only a few thousand hours.

Furthermore, most heat resisting castings for load carrying parts are designed with regard to foundry limitations, so that on the basis of laboratory time-yield values the castings usually figure out to be overstrong. Another point which is difficult to evaluate is the thermal stress set up by unequal heating, end to end, or surface to center, a matter which is often responsible for warping out of usable shape.

Special atmospheres at high temperatures require individual study, and data are accumulating slowly. Statements have been made and repeated about the danger of nickel in alloys in contact with sulphur. Heindlhofer and Larsen appraised the meager evidence in last month's METAL PROGRESS and conclude that in mixed oxidizing plus sulphidizing conditions, 15 to 18% chromium effectively protects iron, while nickel in the absence of chromium (or even with chromium in very high nickel alloys) resists very little better than commercial iron or carbon steel.

Reducing atmospheres at high temperature are difficult to handle in the chromium-iron alloys, which carburize the ferrite and react with any carbides already existing, with the net result that the alloy changes dimension and cracks. The 60% nickel, 15% chromium, 25% iron (Geiger's Type I) is accepted by many metallurgists as standard for carburizing, nitriding, and electrical resistivity; this type also has good working strength in a wide temperature range.

A Swedish alloy containing about 60% iron, the remaining constituents being chromium, aluminum and cobalt, has also proven to be quite resistant to oxygen, sulphur, ammonia and dry carbon oxides. (See letter from E. Öhman in METAL PROGRESS, December, 1931.)

Corrosion Resisting Alloys

Since each major application in corrosion resistance is a problem of its own, remarks on this branch of the subject will be confined to two typical alloys, the "all-purpose" 18% chromium, 8% nickel alloy, and the higher alloys for handling sulphite liquor in the paper pulp industry, and many other corrosive agents.

Alloys of the 18-8 variety are fairly well suited to the foundry art, being less troublesome than the chromium-irons, for instance. They have fair tensile strength, high toughness, and resist most liquors to be handled by industry. All these factors make for growing importance of the alloy. The composition of cast 18-8 usually runs about 19-9, or higher, so the melter can get his analysis within the stable range. Carbon content may range from 0.10 to 0.20, if the casting is not to be welded nor exposed to working temperatures over 800° F., which precipitates carbide from the austenitic microstructure and renders the alloy corrodible to some strong reagents. This is avoided by keeping the carbon below 0.07%, by introducing some stabilizing alloy like titanium or columbium, or by increasing the alloy to say 22-12. It has been shown that silicon up to 1% in these quenched low carbon castings does not promote carbide precipitation and corrosion.

Low carbon castings may conveniently be made in high frequency induction furnaces, wherein there is no danger that carbon may be picked up from electrodes. However, carbon is now reasonably well under control in good melting practice on the chromium-nickel-iron alloys in arc furnaces if the charge consists of low carbon materials. As the carbon content is limited to lower and lower amounts, the heat takes longer, requires more superheat, and there is more chance of foundry rejects. This is probably inescapable, and the purchaser who insists

on low carbon analyses should be prepared to pay for the extra cost of producing them.

Uniformity in production has been achieved to a marked degree. Witness these physical properties of five heats from an acid arc furnace; Brinell hardness varied from 143 to 156.

Heat	Yield Strength	Tensile Strength	Elongation in 2 in.	Reduction of Area
4920	34,300 psi.	75,750 psi.	68%	70%
4926	34,900	76,500	59	61.8
4931	32,400	88,150	53	61.1
4935	33,600	74,550	64	63.3
4940	36,800	76,850	54	58.6

H. C. Cross has studied the creep resistance and endurance of 18-8 castings at elevated temperatures. Split heats were used; only the carbon was different, low carbon being 0.07% and medium carbon 0.12%. Endurance of the low carbon casting was 33,000 psi. at room temperature and 19,000 at 1200° F. For the medium carbon endurance was 34,000 psi. at room temperature and 22,500 at 1200° F. Creep tests follow:

Carbon Content	Temperature	Stress for 1% Elongation in 10,000 Hr.	
		In Secondary Units	Total Deformation
0.067%	1000°F.	17,325 psi.	14,500 psi.
0.125	1000	22,500	19,645
0.067	1200	8,500	8,500
0.125	1200	9,300	9,000

It would seem that medium carbon alloys are better for service at such moderately high temperatures, if the problem of intergranular corrosion is absent.

In order to determine definitely the suitability of the austenitic 18-8 chromium-nickel steels for low temperature engineering applications, a series of tests have recently been conducted. Izod impact tests and bend tests at +30° F., −60, −110, and −300° F. show that stainless steels with carbon content of 0.10% and less are ideal for the construction of equipment needed for many new chemical processes carried out under low temperature conditions, as even at the lowest temperature the ductility remained almost unimpaired and the Izod impact value was practically constant throughout.

Owing to a number of unsatisfactory experiences with castings of nominal 18-8 in sulphite pulp and other corrosive solutions, it is now generally conceded that higher alloy content is necessary to handle the variable mixtures of SO_2 in a digesting system. Considerable experience with 20% chromium, 10% nickel, 0.20% max. carbon, plus 3% molybdenum has been gathered, and on the West Coast it is practically standard.

In the Great Lakes region and Canada, however, many paper technologists prefer a higher alloy, nominally 29-9, with carbon about 0.30% (low enough to be ferritic as cast) and with some silicon for its general founding properties. This ferritic analysis has the advantage, from the producer's standpoint, of requiring no quench from high temperature to fix the microstructure, and therefore it can be made into many castings too intricate for drastic heat treatment. It also has the same order of corrosion resistance as quenched low carbon 18-8, as determined by the Huey test.

The problem of carbon specification is rather more controversial in corrosion resistant castings than it is in heat resistant castings. It is complicated by the fact that the purchaser frequently wants the castings to match the chemical analysis of adjacent equipment made of rolled plate, wherein the analysis has been adjusted for ingot practice and performance in the rolling mill. Likewise the discussion about intercrystalline embrittlement in borderline austenitic alloys like 18-8 has tended toward a belief among those who are not metallurgists that *all* corrosion resistors should have very low carbon to be safe.

As a matter of fact, a carefully conducted test program has indicated that the cast structure (at least of the alloys tested) is more corrosion resistant than the same material after rolling or forging. This is not due to a skin effect, for the superiority exists in cast specimens, machined all over. An explanation offered is that the work of forging or rolling causes some of the solid solution to precipitate sub-microscopic chromium carbides, thus withdrawing some of the chromium from its real job of protecting against corrosion.

Corrosion resisting castings, when they fail in service, frequently fail by selective corrosion — that is to say, accelerated attack in certain regions, leaving the bulk of the casting virtually untouched. In most cases these vulnerable areas are located where shrinkage and segregation would likely appear in a defective casting. Undoubtedly the problem of increasing corrosion resistance (and heat resistance, for that matter) is as much a problem in foundry practice as it is a problem in analysis — if segregation and the production of incipient shrinks and sponginess can be minimized, the service results would be correspondingly bettered.

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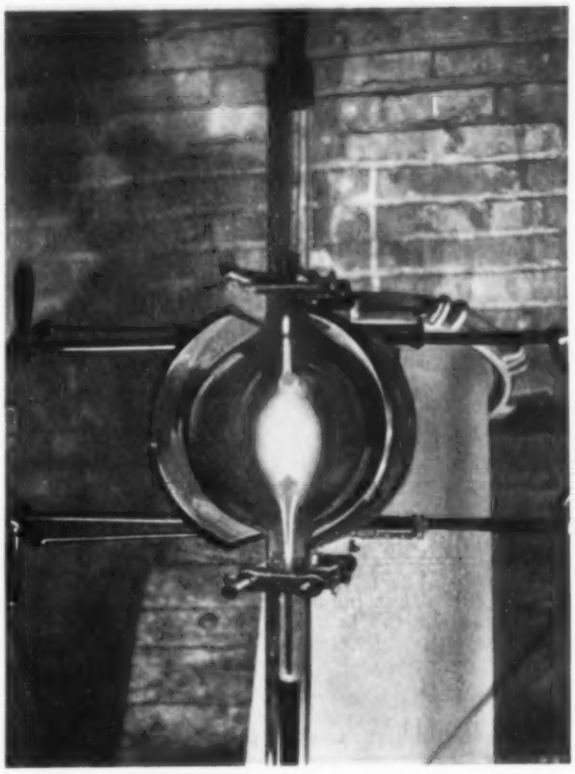

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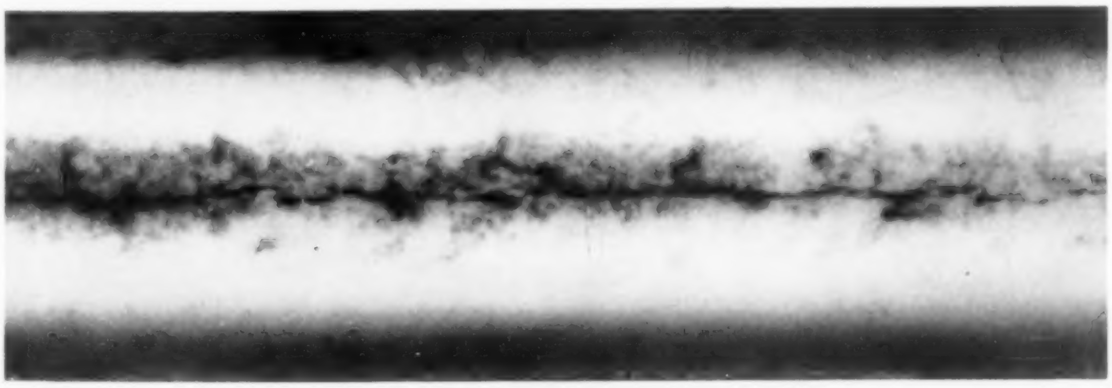
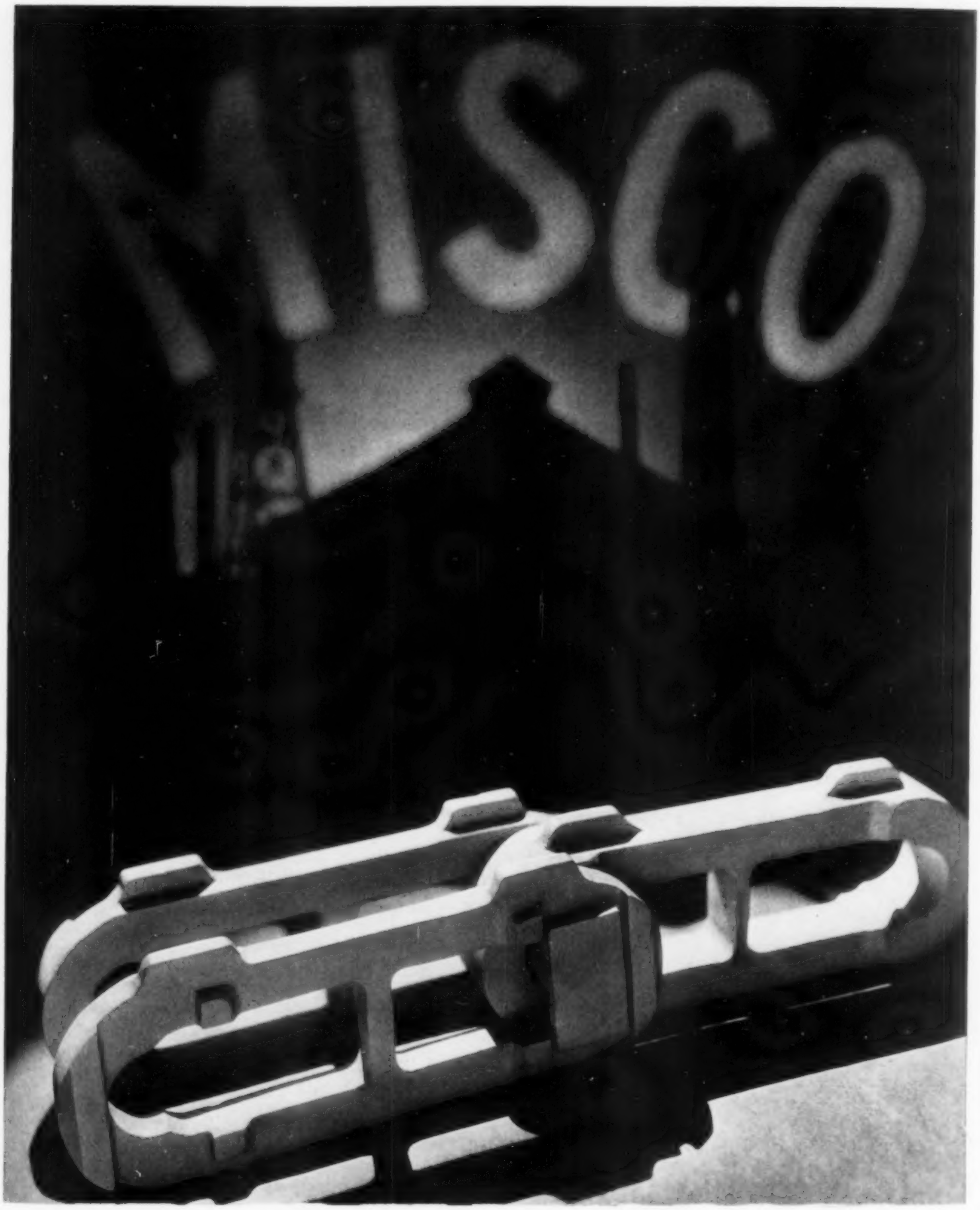


RADIOGRAPH OF INTERNAL CRACK IN CASTING.



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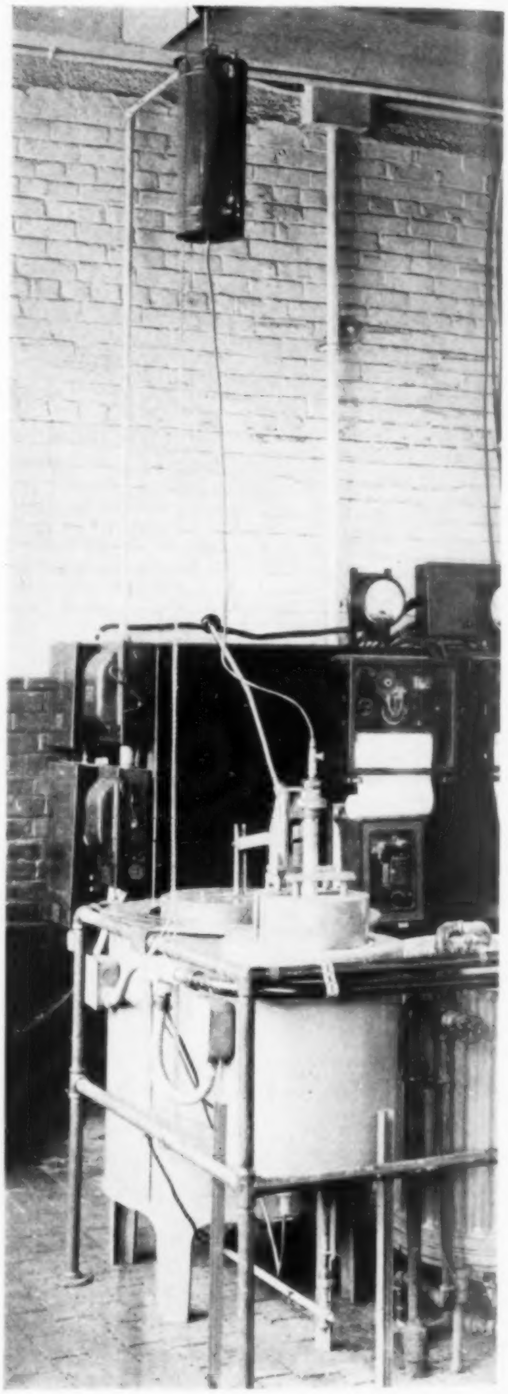

The hardening of various tool steels, including those most susceptible to decarburization in natural furnace atmospheres, will be demonstrated with the L & N Triple-Control Hump Hardening equipment, in Booth 354 at the Metal Show. The rate of heating will be automatically controlled by the temperature-difference method. The tools will be hardened without packs or coatings of any kind. They will nevertheless have no trace of pitting, scaling or decarburization, and the critical of each will be shown by the familiar Hump on the tool's chart. Bring data on tool costs from your own heat-treating department, and learn how quickly a Triple-Control Hump will pay for itself in your plant.

THERMOTUBE DEMONSTRATION

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FURNACES and REFRACTORIES

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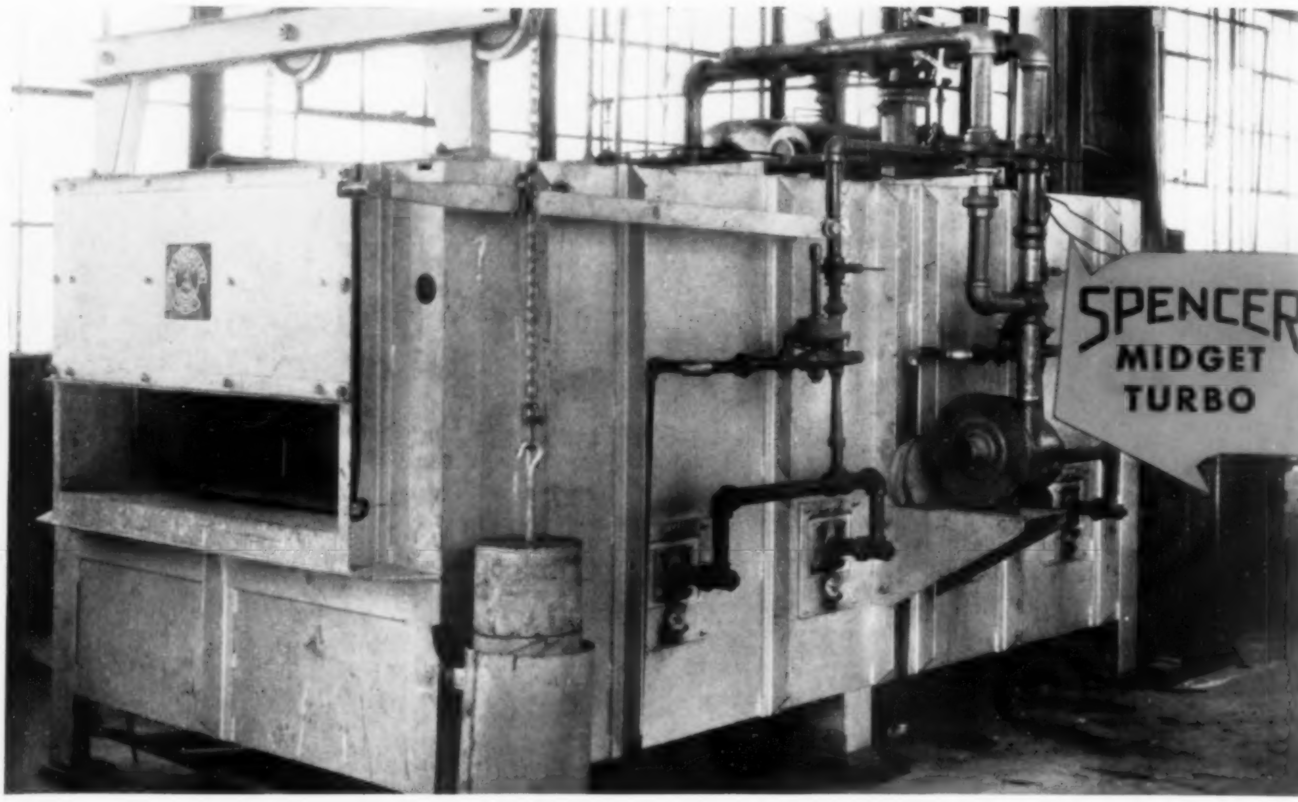

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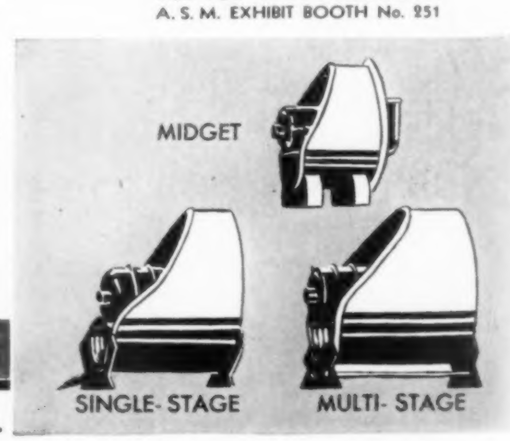

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NEW FURNACES—ESPECIALLY FOR BRIGHT ANNEALING

A MAN does not need to be very old to recall the time when heating furnaces (usually coal fired) leaked at every joint; the buckstays warped, the doors ill-fitted, and the roof perilously near to cave-in.

As soon as production officials realized that it was necessary to heat metal parts uniformly to a definite temperature if the output were to be reasonably constant, these relics were on their way out. Then oil, gas, or pulverized coal, fed through a proper burner, became the order of the day. Heating furnaces were built inside strongly braced steel or iron binding plates, air-tight against leakage and contributing wonderfully to permanence of the installation.

Mechanical handling, other than in car-bottom furnaces well-known in heavy forge and ordnance shops, waited for usable heat resisting metals and alloys. These were coming apace, however. Nickel-chromium alloys were available as byproducts of electrical resistor manufacturers. High chromium-irons were discovered, and soon there was a variety of nickel-chromium-iron alloys for heat resistance. With them really automatic furnaces could be built; and, even more important, furnaces which passed a charge, one piece at a time, through a stationary chamber on rails, rollers, or walking beams (or tumbled them down a slightly inclined cylindrical muffle) and thus approached the ideal of identical individual exposure for each piece being treated.

Here we had fuel economy in properly fired counterflow furnaces, labor economy in mechanical hearths and pushers, and advanced furnace designs that gave uniformly heated zones, under close and automatic temperature regulation. The ideas behind each of these developments were old; pre-War examples of most modern types could also be cited, but it took the commercial and economic conditions of post-War life to attain their wide acceptance. It was perhaps not strange that the furnace industry then rested on its oars — all except the youthful electrical end, which vigorously pressed the advantages of cleanliness and mobility of electrical heat.

It resulted that a pronounced trend was noticeable in the late twenties toward electricity as a heating medium for the rather milder temperatures. The safe limit of the nickel-chromium heating elements has more recently been raised by the use of silicon carbide resistors. A new iron alloy resistor is also reported from abroad. Recent installations for heat treating strip and baking of lacquered items have even used the principle of high frequency induction currents for heating. During these years furnace users learned to demand cleanliness, reliability, and flexibility of a furnace, which could be placed directly in a production line, like any other machine tool.

All the time there was a growing insistence for greater accuracy in heating, wherein each part of each piece is heated according to a precise time-temperature cycle. This resulted in numerous modifications in design of furnaces for all types of fuel. In the batch-type furnaces this resulted in "program control" of temperature, and blowers to circulate the hot atmosphere. Continuous furnaces are a different problem. Stokers, conveyors, blowers and atmosphere control are well developed, and uniformly heated steel has been satisfactorily produced, even in coal-burning furnaces.

Another important trend has been the practical development of a number of old ideas about heating in controlled atmospheres. Whereas relatively expensive atmospheres of hydrogen gas had been used here and there, the discovery of low cost mixtures of neutral or reducing gases greatly widened the commercial scope. Included in this category are continuous nitriding, gas carburizing, and bright annealing — the latter of which may be characterized as the most notable progress in heat treating in recent years.

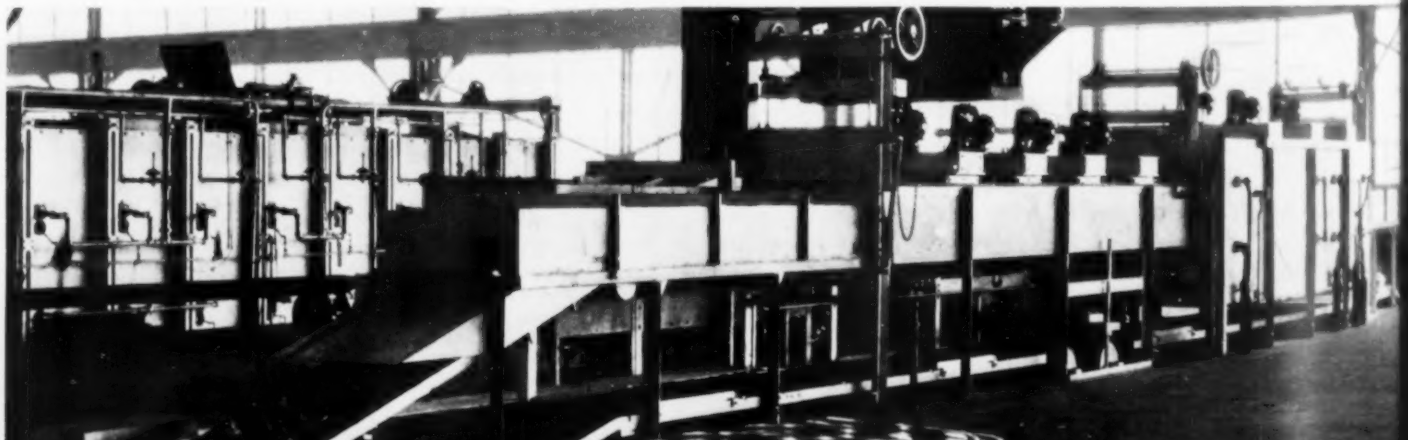
Faced with vigorous promotion of electricity as a competitive heat source, the proponents of gas-fired equipment started an intensive study of their heating medium and their equipment — studies which are still being promoted. A number of improvements have been introduced into gas furnaces, such as better design of furnaces, burners, and flues for uniform temperature, better volume control, better insulation, better understanding and application of the laws of combustion. Associated economic factors have been the extension of natural gas lines into established manufacturing regions, and marketing in bulk of hydrocarbons like butane or propane.

In any consideration of relative advantages of furnaces, it should be borne in mind that a unit of heat is a unit of heat, irrespective of its source. It is the design and operation of the furnace and its auxiliaries (that is, the *control* of the heat) that are responsible for the ultimate results. The practical problem is to secure a design of furnace and a method of heating which will result in the maximum convenience and minimum cost per accepted piece under the local conditions existing at the place where the furnace is to be installed.

Furnace for Copper Annealing

Bright annealing has been adopted by the copper mills to meet their customers' demand for tube and wire with smooth (unetched) surfaces, unstained and dry. Even though the majority of uses to which copper tubing is put may not require such a superfine surface, the purchaser who pays the price of copper demands a flawless article.

The art is old, in the sense that water-sealed furnaces (both of the batch type and the continuous type) have been installed in brass mills for many years. These annealed copper tubing without oxidation, but since the material entered



View From Discharge End of Continuous Furnace for Bright Annealing Copper Products, Such as Coiled Tubes. Gas preparation unit and control panels are hid behind furnace

and was discharged through water, the ends had to be plugged and it had to be dried at the end, with the accompanying "water spotting."

The refrigerator industry desired a soft copper tube of thin wall, free of oxide or water stain inside and out. As pointed out by Mr. Crampton in METAL PROGRESS in June, this type of product could then be produced only by filling the tube with a fuel gas and bright dipping to remove the "water marks" at the end of the operation.

That was expensive, and it seemed logical that the outside could also be protected by a gas atmosphere. The temperature required is only about 1000° F., and since the tubing comes from the draw bench without any oxide, the problem was to maintain that surface unchanged. What was required was a long muffle with a cooling chamber extension, and simple gas traps, through which traveled a woven belt conveyor of heat resisting metal. A real problem consisted in cooling the work and its conveyor to 200° F. (where oxidation is no longer a danger) without extending the muffle to an impracticable length.

Probably the greatest difficulty to be solved was elimination of sulphur in the gas atmosphere. The least trace of it in the form of organic compounds will discolor the copper. Many natural and artificial gases are low in sulphur, and that which exists can be scrubbed out to a harmless amount, but it was another thing to eliminate traces (0.05 grains per M.cu.ft.) of the more complex sulpho-hydrocarbon compounds contained in some commercial fuel gases.

How well the job has been done can be realized from Mr. Crampton's words: "As a result of all these items copper tube can now be obtained for refrigerator or other uses, bright annealed, clean, and dry, and from the standpoint of quality is probably one of the most perfect materials ever produced in our industry."

Similar considerations led to adapting the same ideas to the annealing of fine copper wire, either in process or at the end, to a dead soft material. Yet it should not be assumed that all problems connected with copper have yet been solved. It may be said that it is now a simple matter to bright anneal metal which has been deoxidized with phosphorus, or that which has been refined in such a way as to be oxygen-free. Ordinary "tough pitch" lake copper or electrolytic copper, however, contains considerable oxide in a copper-copper oxide eutectic, the oxygen having been picked up during the final melting prior to casting into ingots, bars, or slabs. Atmospheres which will reduce copper oxide *at* the surface are also likely to reduce copper oxide *under* the surface, producing a slightly honeycombed surface layer, or penetrated by a few shallow microscopic cracks where water vapor has worked its way out of the metal. Fortunately there is a mitigating circumstance that much fine wire may be annealed below 600° F., and no embrittlement takes place at that temperature.

Bright annealing of brass presents its own peculiarities, and this matter was described briefly by R. J. Cowan in January in METAL PROGRESS. Both water vapor and carbon dioxide oxidize heated brass, and enough of these oxidizing gases may be liberated from the metal itself to spoil the theoretical result in an inert atmosphere. Mr. Cowan found that relatively small amounts of methanol vapor acted as an inhibitor and completely prevented the formation of oxide films; further that hydrogen, either free or nascent, will act similarly if other conditions are correct. Others recommend a little zinc vapor in a non-oxidizing atmosphere. Still another school of thought contends that discoloration is due to irregular migration of zinc at the surface.

Brazing Furnaces

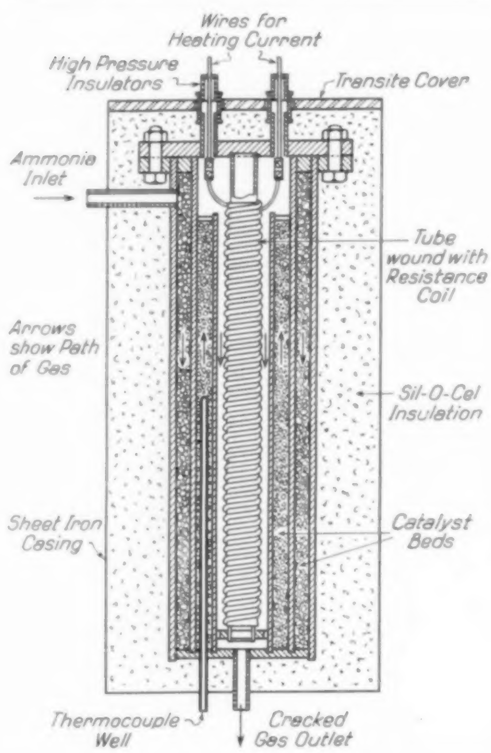
A renewed interest in continuous "brazing with copper" is another outcome of the new knowledge about gas atmospheres. The operation is not new, but until recently it was carried on in an atmosphere of hydrogen, or hydrogen and nitrogen, which are rather expensive gases unless they are available as byproducts.

As is doubtless well known, the true brazing operation consists of dipping a tightly fitting assembly of steel parts into a well-fluxed pot of melted brass. The molten metal penetrates into all the joints by capillarity, and wherever the brass has come in contact with clean steel a true weld has occurred, making a joint of surprising strength.

Even better joints can be made with copper. The temperature required is higher than for true brazing (and of course much higher than required for annealing of copper) where steel parts oxidize and cannot be "wetted" by the copper. In the modern operation of brazing with copper, oxidation is prevented by heating the assembly in an atmosphere with more or less hydrogen — in fact, any scale or oil is removed by the hot hydrogen, leaving a pure iron surface ready for the copper to spread over it. Instead of dipping the parts in copper, it has been found that a copper wire wrapped around a joint, a piece of

shot-copper in some cavity, or even some copper powder in lacquer, daubed on, will suffice. As the temperature passes 2000° F., this copper melts, spreads over the adjoining iron (already deoxidized by the hydrogen) and is drawn deep into all joints by capillary action.

An important advance toward cheap atmospheres for this and other heat treating operations was the development of a dissociator for anhydrous ammonia (NH_3) as described by J. F. T. Berliner in METAL PROGRESS, April, 1932. In this dissociator the tanked anhydrous ammonia is connected to an alloy tube which contains a suitable catalyst and is electrically heated. Conditions are as shown in the adjoining sketch. This improved equipment brought the price of mixed gas of extreme purity (75% H_2 and 25% N_2) down to where it could be more freely used in furnaces with positive gas locks. Manufacturers of compressed oxygen also are marketing a high-purity gas containing 93% nitrogen, 7% hydrogen in cylinders where quantities involved are too small or operations too tentative to warrant installation of gas producers.



Cross-Section of Ammonia Dissociator for Producing Dry Mixture of Hydrogen and Nitrogen From Ammonia

Next came devices for making deoxidizing atmospheres quite cheaply from natural or city gas. Costs range from 15 to 25¢ per M and the copper brazing operation then became commercial for an increasing number of operations where steel stampings are joined together to make all manner of things, from finned radiators to pulley wheels and golf club shafts and even to entire refrigerator units. There is no limit to the number of joints that can be made in a single assembly, simultaneously and automatically. Obviously, this can be done continuously in a furnace with a moving hearth. The only direct labor is loading in and loading out.

Before leaving the interesting subject of furnaces for heating non-ferrous metals and alloys in controlled atmospheres, mention may be made of the heat treatment of strong magnesium alloys in no atmosphere at all — that is, in a vacuum. It has been found that a certain amount of damage is done to the physical properties by a long solution treatment at moderate heat — a damage by oxidation which starts very slowly, but proceeds at an accelerating rate. A simple remedy is a closed furnace operating in a vacuum. Heating is done with the air vigorously circulated by an internal blower. On reaching temperature, however, the furnace is connected with a vacuum line, and the required soaking period proceeds with the air exhausted to a low pressure.

During recent years various extensions of the above general ideas have been made to steel. Here the problem is more difficult because annealing temperatures for steel are so much higher than for copper, and because steel is a complex alloy containing an essential element carbon which should not be increased or decreased while any oxide is being removed from its surface, even by hot gases which contain a large proportion of combined carbon and oxygen.

Control of Furnace Atmospheres

Some extensive studies have been made on the reactions and equilibrium conditions between iron, carbon, and the various gases appearing in quantity in the furnace atmospheres, such as oxygen, hydrogen, water vapor, carbon monoxide, carbon dioxide, methane and ethylene, both singly and in combination, to discover in what range of combinations and temperatures steel may be heated and deoxidized without being decarburized or carburized. (In some very special cases decarburization may be the aim; in others, carburization. Then the matter becomes one of case hardening, a subject which is treated at some length in the section on heat treatment, page 99.) It can readily be seen that the general problem is extraordinarily complex (but is simplified by limiting the reactive gases entering the annealing zone to CO, CO_2, H_2, and H_2O. As Messrs. Marshall and Agens have shown in METAL

...OGRESS for September, 1933, when city gas is ...rned with two to three parts of air and cleaned ... ethylene and oxygen, the ratio between CO_2 ...d CO falls naturally into a value which will ...t oxidize steel from annealing temperatures down to air-tarnishing temperatures (approximately the range of 1300° F. down to 600° F.). The proportional amount of moisture in relation to free hydrogen depends on the ratio between CO_2 and CO, but the moisture can be adjusted so it will not oxidize the steel when annealing or cooling.

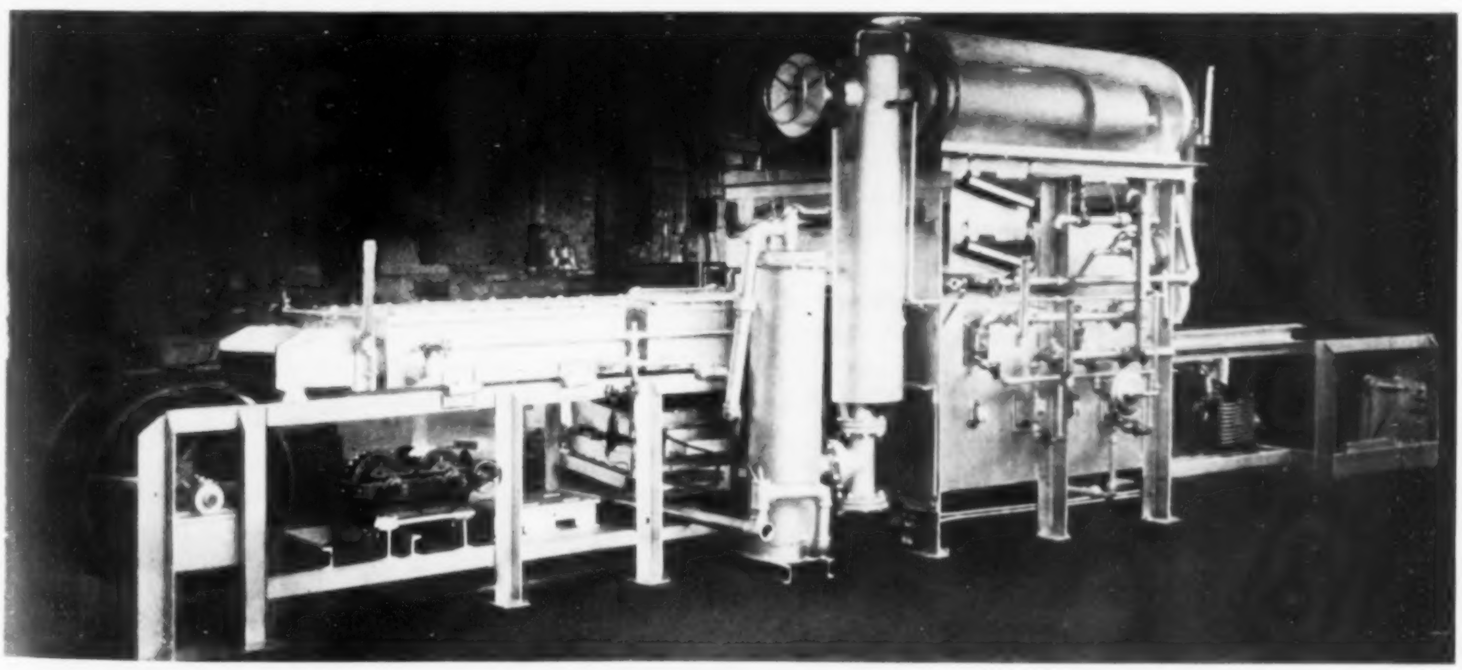
Such a proper mixture of gases is definitely oxygen-consuming, and therefore will render harmless any air trapped in the charge of metal during the heating cycle, and reduce oxide on the metal itself. However, slight amounts of free oxygen entering during the cooling cycle cause the outer portion of a coil or stack of sheets to tarnish, even in a large excess of hydrogen at about 600° F.

Etching of steel sheets is also a problem. This etching is caused by certain gas reactions wherein the iron acts as a catalyst. Etching is controlled simultaneously with oxidation by the above methods. While these gas mixtures will deoxidize and not etch, they also decarburize the steel slightly. Fortunately the principal commercial demand is for annealing of low carbon steel where slight decarburization is not nearly as serious a matter as an etched or discolored surface would be.

As a result of the above scientific conclusions, various pieces of equipment are now on the market for producing non-oxidizing atmospheres for steel at low cost. The gases originate as fuel gas (natural gas, city gas, coke oven gas, or blast furnace gas) and are "cracked," or else partly burned with a definite amount of air. (Some protective atmospheres start from oil fuel.) If a large excess of hydrogen is necessary or desirable, a hydrocarbon may be "cracked" with steam at high temperature, sometimes with a catalyst. On the other hand, it is often merely necessary to mix the fuel gas prior to use with spent or flue gas.

The simplest "converter" or cracking unit may be a tube, or even a brick chamber, heated to correct temperature, through which a fuel-air mixture passes, and the oxygen in the air combines with the hydrogen and hydrocarbons in the fuel. Ordinarily the hot flue gases are then cooled with a water spray, undesirable sulphur compounds absorbed by iron filings or some similar substance, and excess moisture refrigerated out or taken out by sulphuric acid or silica gel. Starting with, say, commercial gas, it will be found that the relative proportions of H_2, H_2O, CO and CO_2 can be kept reasonably constant by controlling the ratio between fuel gas and air in the converter, and is simply done by a motor-operated gas-air mixer and blower.

First application of these facts to steel production occurred in the form of electrically



Continuous Furnace for Bright Annealing Miscellaneous Small Parts, Installed by Hess Bright Co. Gas preparation unit and controls are included

heated batch-type furnaces for expensive or highly finished sheet, strip, and wire. Many interesting designs have been made. One is an "elevator" furnace placed on columns; the bottom may be lowered to floor level, unloaded and loaded, and then raised up into place. The furnace itself is like an elevated cover or box, insulated, and with electrical resistors properly placed on all surfaces. Rapid cooling in non-oxidizing surroundings is effected by a circulating system which pumps the hot atmosphere out over a finned tubular-type surface cooler (water cooled) and back into the hot interior. Furnace loads can thus be cooled in about half the time required if under a steel hood in the open air; uniform cooling due to the circulating atmosphere also improves the flatness of the cold sheets. Early commercial installations of this sort were for annealing silicon steel transformer sheet in a hydrogen atmosphere; considerable extra expense for hydrogen is still warranted by the greatly improved magnetic characteristics of the alloy sheet. A representative atmosphere for common steel is about 6% CO, 6% CO_2, 6% H_2, and balance N_2.

More recent designs are of the "bell" type and utilize movable furnace covers, either electrically or fuel heated, and move the hot cover from one loaded base to another. A notable installation of this sort at one of the large steel mills was described in METAL PROGRESS for August, 1933. Coils of low carbon steel strip (all of about equal internal diameter) are stacked on a refractory base to form a pile with a large cavity down the center of the stack. Over the pile of coils is placed a gas-tight cylindrical cover of thin sheet of high chromium, heat resistant alloy, which projects into an oil seal in the base. (An inner cylinder, open at top and closed at bottom, projects through the center of the coils, to clear the central heating elements suspended from the top of the furnace.) After this cover is adjusted, the air inside is replaced with cleaned, dry coke oven gas, a hot bell from another base lowered in place by an overhead crane, and the current turned on. After 6 to 10 hr. at 1250 to 1400° F., depending on the nature of the charge, the hot furnace is transferred immediately to another waiting charge without wasting heat; the hot strip, still in a gas atmosphere inside the covers, cools by convection to surrounding air. Energy required for the heat amounts to from 140 to about 175 kw-hr. per ton of annealed product, depending principally upon the carbon content if the loading characteristics are the same.

In this particular operation, the coke oven gas is very slightly carburizing to the low carbon steel strip. It may deposit a thin layer of soot on the outside coil, which can be cropped off after the final pinch-pass. As compared with old style fuel-fired furnaces for annealing in boxes, the higher cost of electric heat per B.t.u. is more than overbalanced by better furnace insulation, by a quicker heating cycle due to less dead load (80 to 90% of the total material heated is product — strip), and by a smaller differential between temperature of the source of heat and the charge.

Gas for Bright Annealing

In view of the facts about equilibrium proportions of CO, CO_2, H_2, and H_2O stated several paragraphs back, several metallurgists have held to the idea that the only way to bright anneal in the true sense of the word would be to use gases which are carefully dried and completely free of oxygen or carbon dioxide. Such a gas would be purified nitrogen containing enough hydrogen to deoxidize but not enough to decarburize (less than 14% for low carbon steel) — a gas which heretofore has been available principally from the cracking of ammonia. A unit has recently been put in operation which makes 14,000 cu.ft. per hr. of such mixed hydrogen-nitrogen from natural gas at a price which warrants its use in bell-type strip furnaces as described just above. Preliminary reports are that it is able to anneal any commercial steel except stainless on a tonnage scale without trace of oxidation, carburization, or decarburization.

Other types of sheet annealers have given good account of themselves, wherein the movable hood takes the place of the bulky steel box to cover a pile of soft steel sheets, but the bell itself has heating elements in the form of heat resisting metal tubes within which gas is burned. Hot spots are avoided by utilizing the principles of diffusion combustion and avoiding turbulence. Blowing cold air through these tubes at the end of the soaking period will also cut the total time required for the annealing cycle. To move such a cover from pile to pile requires only the breaking of three hose joints, one on the fuel gas line, one on the air line, and the third on the line delivering prepared gas to the inside of the bell for deoxidizing atmosphere.

Such equipment has been attractive to sheet mill operators because it is relatively inexpensive and can be bought as *(Continued on page 84)*

BETTER PRODUCTS FROM IMPROVED MELTING FURNACES

IN ANY REVIEW of recent progress in the art of melting metals it would be unfair to plunge directly into a consideration of electric furnaces, and by saying nothing about fuel-fired furnaces thereby infer that there has been nothing worthy to report. These older methods are now common property; no organization has a large financial interest in the vigorous promotion of one type; improvements therefore are matters of detail and are usually the result of careful study of the individual installation and are made to adapt a furnace to a specific duty.

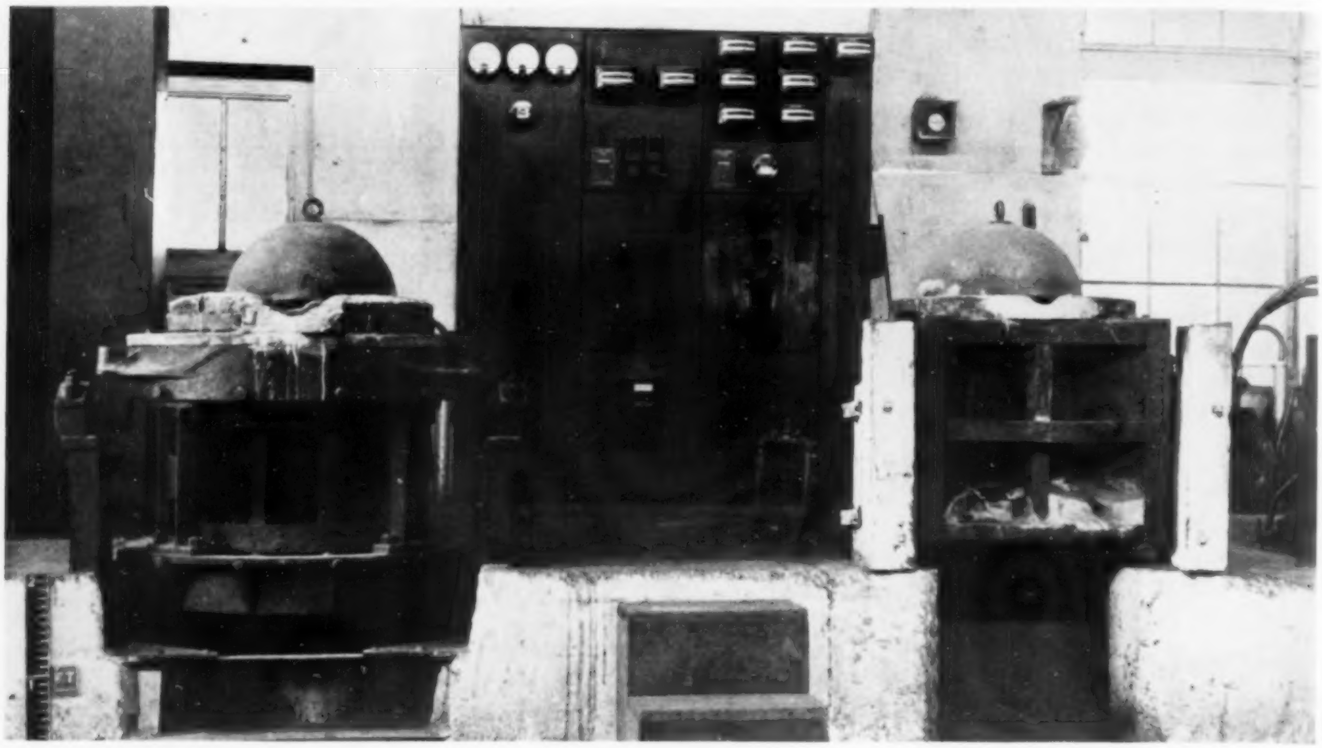
The metallurgist studies the refining operation and works toward his ideal slag control, deoxidizing routine, and ingot practice; this has improved the characteristics of the product but has brought new problems to the refractory maker. The fuel engineer studies the correct utilization of the most economical fuel; the clearest evidence of changes has come about by his insistence that the furnace and all its auxiliaries be tightened up, that dampers be automatically controlled to keep the pressure slightly above atmosphere, that reversals on regenerative furnaces be made at the correct time and in proper sequence, and that the fuel is properly burned at the right place.

An ingenious device can be briefly described as an instance of combustion control. A small stream of flue gas is mixed with a measured amount of oxygen and passed over a thermocouple junction. A second stream over a second couple is mixed with a measured amount of fuel gas. If the flue gas contains unburned fuel, the first couple gets hotter, and this closes the fuel supply or increases the air. If there is an excess of oxygen in the flue gas, the second couple gets hotter, and this acts in the opposite direction.

Induction Furnaces

High frequency induction furnaces have been described so often that all readers should know the principles of operation. It may be said that the recent advances have been made in tonnage production of ordinary material — the role of the furnace as a handy melting unit for any of the high alloys having been well established. Experimental work also indicates that it has merit as a refiner when melting with proper slags.

It has been found that the frequency of the alternating current sent through the windings (water-cooled copper coils) can be standardized at about 1000 cycles per sec. There have been available now for nearly ten years motor-generator sets capable of producing these frequencies with a conversion loss of 10 to 15%. The largest size of furnace takes up to 1250 kva., and is installed in the Chicago district to serve a 4-ton furnace. With these motor-generator sets, and with necessary capacitors mounted in oil-cooled tanks, as rugged as modern central station ap-



Sixty-Cycle Induction Furnace (Shielded Yoke Type), 1000-Lb. Capacity at Left, and High Frequency of Same Capacity Arranged for Bottom Tapping, in Barberton, Ohio, Plant of Babcock & Wilcox Co.

paratus, the difficult electrical problems of small early installations have been solved.

With four 4-ton furnaces here and abroad, it is obvious that this method of melting has grown beyond the laboratory stage, or for the production of small heats of special analysis (for which it was especially popular during the depression) into a primary source of steel. It is interesting to speculate on the economics of such a situation:

In most installations (other than in foundries) electric furnaces have been put into plants which were built around other and larger types of melting furnaces. If a melting department were installed from the ground up, it would be found that the cost of furnaces and electrical auxiliaries would be much more than open-hearth furnaces, but there are compensatory items. D. F. Campbell in a paper before the British Iron & Steel Institute compared six 75-ton open-hearth furnaces producing 6000 tons of steel a week with ten 6-ton high frequency units giving the same output and casting direct into ingot molds. Instead of 100-ton cranes and buildings of corresponding strength, the maximum would be 10 tons. A more regular supply of ingots from a battery of electric furnaces would avoid much expense in soaking pits. Charging equipment is entirely different and standby heating charges are zero. Ground area would be 70,000 and 32,000 sq.ft. respectively. Summing these items, it was found that the electric furnace plant is actually cheaper in first cost than the conventional open-hearth installation.

The possibilities of controlling the gaseous atmospheres offered by the induction furnace are of special interest to the metallurgist. Both melting and casting under vacuum are being widely used in laboratory studies of gas-free metals, and one large industrial installation of this kind is in successful operation in Germany. A number of heats of corrosion resisting alloys have been made in one of our own large alloy foundries under different types of gaseous atmospheres.

Most of the foreign coreless induction furnaces use acid linings, whereas metallurgists in this country have favored basic linings of magnesite. Americans are now turning toward the cheaper but less durable acid refractories made of very pure silica sand of suitable grain size, mixed with 15% silica flour and moistened to a ramming consistency with silicate of soda solution. The silica lining will stand temperatures up to 3000° F. for short holding periods, and this is high enough for most steels; it wears away gradually by fluxing.

The electrical characteristics of an induction furnace depend upon the frequency of the exciting current to such an extent that the successful coreless induction furnace is universally known as a high frequency furnace. Nevertheless, the opportunity of avoiding the expense of installing frequency converters has caused some extended experiments with "net-work frequency" (that is, the 60-cycle current standardized for long distance transmission). Changing the furnace from one of 960 cycles to 60 cycles will quadruple the ampere turns required in the primary coil, and that means larger copper loss and lower electrical efficiency. While no frequency converter is required, there must be voltage transformers and larger capacitors. Consequently it is a question of balancing costs of the various items of electrical equipment.

One advantage is in the ease of shielding the external portion of the furnace from parasitic currents, a matter of increasing difficulty as the size of the furnace increases. The power factor can be improved by magnetic yokes, which consist of vertical stacks of laminated steel just outside the inductor coil, from top to bottom and underneath until they join at a common path. A disadvantage is the necessity for more bulky scrap in the cold charge, or a button or "heel" of metal left from the last heat.

A 1000-lb. furnace of this type has been in operation at Babcock & Wilcox plant, Barberton, Ohio, principally on alloy cast iron, for several years. (Dr. Hans Diergarten has recently forwarded a letter for publication in the next issue of Metal Progress about the development of three-phase low frequency furnaces in Germany.)

Arc Furnaces

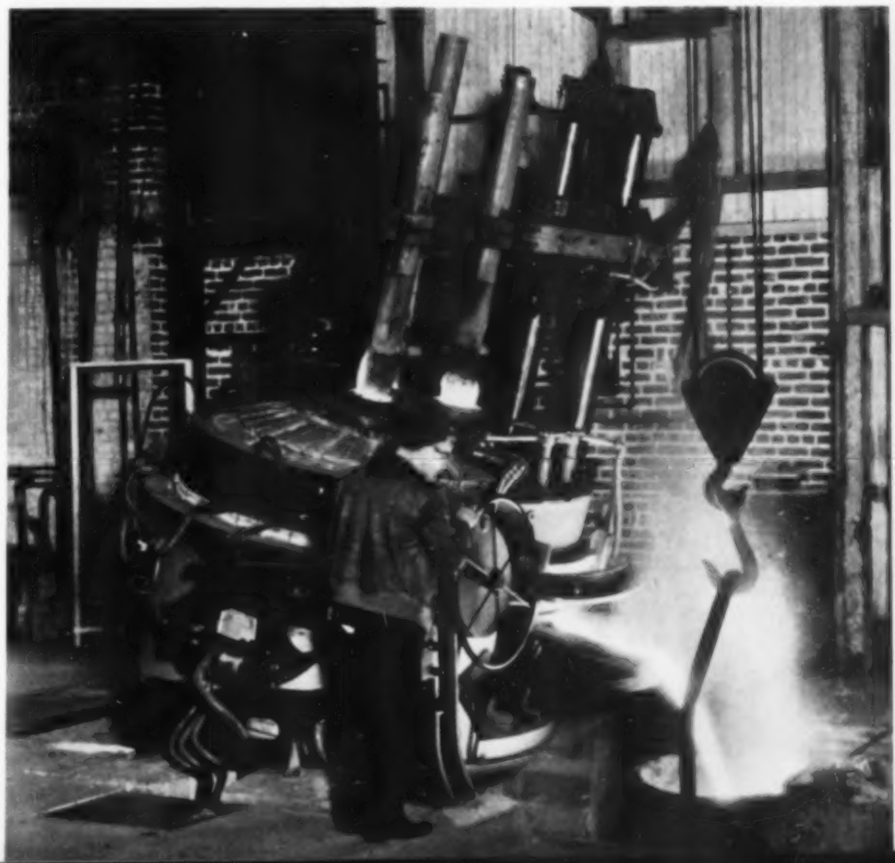
Mechanically, the most important change in arc furnaces has been toward top charging. Twenty years ago, more or less, there were some small single-phase furnaces in existence with the cover hinged at the back, like a coffee pot, but this was not very adaptable to the more massive electrode hoists on a three-phase furnace (the design now practically standardized for direct arc furnaces). A stout boss at the rear of the roof is engaged by a moving plunger which is raised vertically about a foot and rotated about 90° simultaneously, so that when the furnace is open for charging the roof and attachments are not tilted, but are moved aside so a drop-bottom bucket can dump its charge into the hot, empty shell. By this means a furnace of any capacity can be tapped and recharged within 5 min. Comparative figures for two furnaces on the same platform, the same except that one is top charged and the other is door charged, show that the average production over a period of months is 30% more per man-hour with top charging.

Electrically the principal change has been to rely upon tap changer transformers rather than switches external to the transformer to change the voltage. There may be eight or nine of these taps in the transformers; usually three or four of these taps are used for operating and changes made by a manually operated or motor-operated device.

Another interesting development of the electric furnace art has been the adaptation of the rocking type of single phase indirect arc furnace to iron melting. This furnace has been widely used for melting non-ferrous foundry alloys; the arc, struck between two electrodes at the center of a barrel-shaped furnace, heats the metal below and the refractory lining above by radiation. The refractories are washed and cooled by rocking the furnace slowly back and forth, so the lining carries its acquired heat into the bath. The furnace is tight and is operated solely as a melter, without a slag.

Such an adaptation to iron melting has been delayed for two major reasons — first, a diversified demand for high strength cast irons, and second, the development of a suitable and economical refractory. In the furnaces melting cop-

Three-Phase Direct Arc Furnace in Foundry of General Metals Co., Oakland, Cal.



per alloys a high-alumina firebrick has been quite satisfactory; in these the maximum temperature seldom reaches 2300° F. However, many of the new cast irons acquire their enhanced physical properties from a high superheat — up to 2950 and even 3000° F. Such temperatures can be resisted by the new mullite refractories described in the section on refractories, page 77. First success was had by tamping in a graded mix of crushed sillimanite, and burning it into a monolith (and converting the sillimanite into mullite, which is the stable form at high temperature) by turning on the power with an empty furnace. More recently a line of standard shapes made of diaspore clay, burned into mullite, has been placed on the market, and good records are being made with 9-in. linings of this material.

Applications

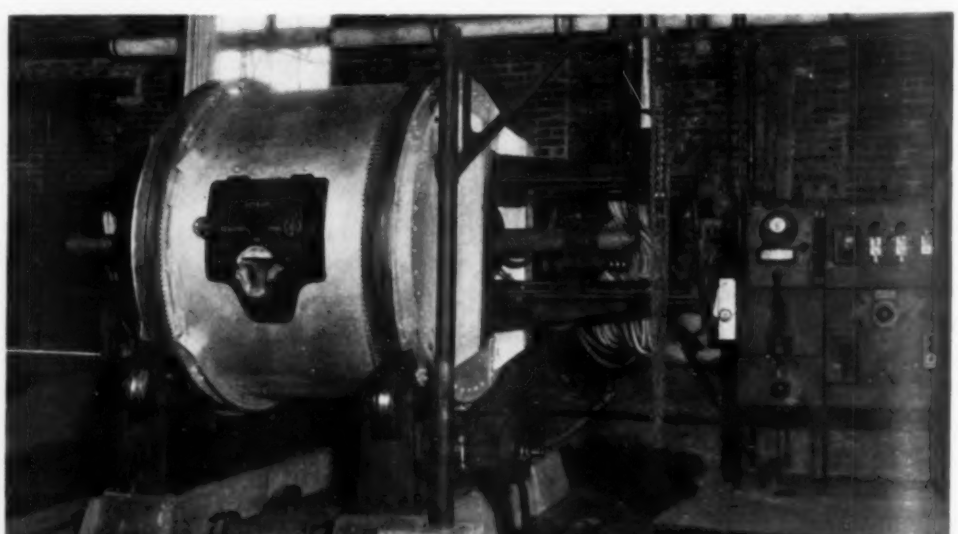
The most interesting new application is the melting of cast iron, or the duplexing with cupola for superheating or alloying, and the production of white iron for short cycle malleable. Aside from the melting of iron which started on the West Coast and in Canada during the War, where electricity was available and coke scarce, the first gray iron made electrically for its special properties was produced in a 6-ton direct arc furnace in the McQuay-Norris foundry in St. Louis in 1919 and cast into piston rings. This first furnace is still in operation. Most of the present furnaces making "high test iron" are relatively small, say ½ to 2 tons capacity. They work either on cold metal, or are duplexing with a cupola, depending upon the tonnage to be cast in the day.

Enough is known about the art to insure high quality in the product; some foundries are willing to accept specifications on cast irons, alloyed and heat treated, to meet such properties as 50,000 psi. ultimate strength and 15% elongation, 75,000 psi. ultimate and 10% elongation, or 100,000 psi. ultimate and 6% elongation. The difficulty is in finding customers who are willing to pay a higher price for the product, even though a gray iron casting may be redesigned to weigh half as much in the high strength varieties. The physicals quoted above really establish a properly made iron casting in competition with steel castings and many steel forgings, and have been responsible for a considerable shift in business.

The principal outlets so far have been to the makers of gas engines, for cylinders and cylinder heads, camshafts, crankshafts, brake drums, valves and tappets, although the electric industry, refrigeration industry, farm equipment industry, household device manufacturers, and heavy machinery industry absorb a considerable tonnage of alloy or high test gray iron.

Much of the production is alloyed with fractional percentages of nickel, copper, chromium, and molybdenum. For this purpose, special briquettes of ferro-alloys have been devised, for adjusting the chemical composition in the cupola without undue loss to the slag. "Baby" furnaces of both the direct arc, induction, and indirect arc have also been installed for melting ferro-alloys in quantities needed to convert occasional ladles of cupola iron to the various alloy cast irons as ordered.

Another important discovery has been that arc furnaces can be operated on high chromium steels (stainless and heat resisting) without running the carbon up beyond specification. This is more fully discussed in the section on alloy castings, page 51.



Indirect Arc Furnace (Rocking Type), 3000-Lb. Capacity, in Carondelet Foundry, St. Louis

INSULATING AND HIGH TEMPERATURE REFRACTORIES

METALLURGICAL investigators and technicians were among the first to feel the need of refractories of very high resistance, much above the capabilities of articles made of fireclay. Consequently, they eagerly adopted for their uses such electric furnace products as fused silica, graphite, silicon carbide, and alumina. These advanced refractories were first available for research equipment like pyrometer protection tubes, furnace linings, and crucibles; later they were applied to extensive use in industry.

On account of space limitations the present article deals, not with such refractories originating from an electric furnace product (consideration of which will be deferred to a later issue), but with improvements in refractories made from natural clays and rocks. These improvements have become available as a result of insistent demands by glass makers, steam power plants, and the cement and lime industries. They may be considered under three heads, (*a*) insulating refractories, (*b*) high alumina refractories and (*c*) refractory cements and ramming mixes.

Such developments have resulted in a spectacular improvement in the performance of furnaces in intermittent duty and have helped to correct many a difficult problem in melting.

Insulating Refractories

Insulating bricks have been on the market for years. The best known of the older varieties use for raw material diatomaceous earth, the remains of billions of small marine animals which build themselves a skeleton of silica. They are good insulators on account of the cellular nature of the material which traps stagnant air within the pores, but had not been used in contact with hot atmospheres or metal because of the danger of softening and slagging. In common with other materials, the better the insulating qualities, the poorer the heat resistance. Consequently they are being principally used for outside courses of furnace settings where true refractory bricks have carried the load and resisted the hot contents.

That there can be a combination of insulating power and high heat resistance is a relatively new idea. Such insulating refractories are generally a bloated kaolin or high alumina clay of unusual purity (although diatomaceous earth is also useful). Their density will vary from about 35 to 55 lb. per cu.ft. (as compared with 125 to 145 lb. for a standard firebrick) and this gives an idea of the proportion of voids. Light weight is of importance in portable furnaces, in doors or car bottom hearths, and in very large furnaces which require suspended roofs, either flat or arched. Bricks of various manufacturers differ somewhat in the size of the pores, ranging from very fine to quite coarse. Users appear to favor

the brick with fine texture; theoretically this should make for high resistance to flow of heat at the higher temperatures.

Unfortunately there are no standardized tests for those characteristics of firebrick which are of most interest to a furnace builder or owner, except strength when at high temperatures. These may be listed in order as: (*a*) Uniformity, (*b*) shrinkage at heat, (*c*) spalling, (*d*) physical strength, (*e*) insulating value, (*f*) thermal capacity.

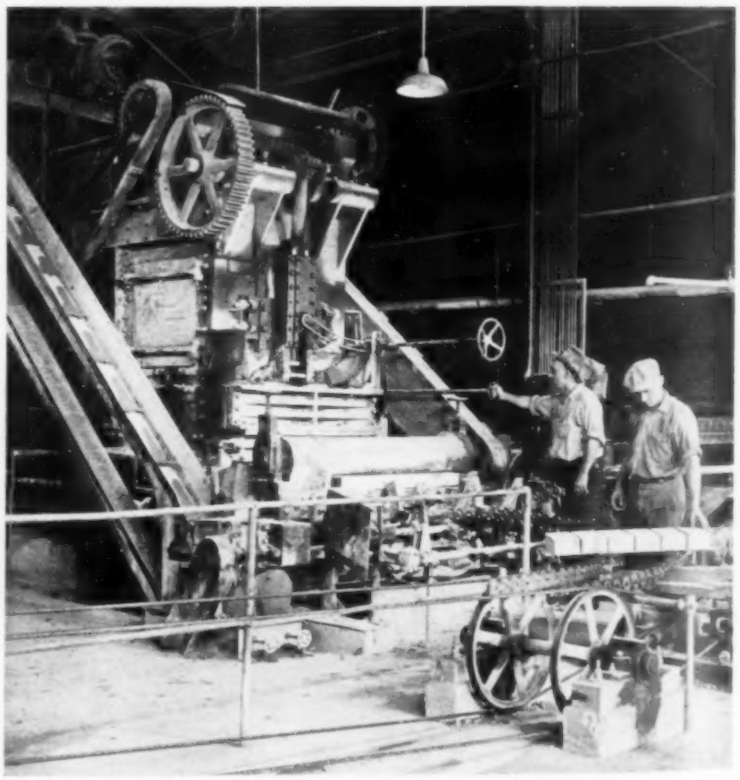
Uniformity is of the greatest importance to insulating refractories, because furnace structures built of them are commonly thinner in wall than when ordinary firebrick are used. Thus the failure of a single brick in a furnace wall might cause the whole thing to be dismantled to make the repair. In thicker walls of ordinary refractories bonded together with headers, a sporadic failure usually means only local trouble which can be patched up.

Shrinkage of the brick after heating to operating temperature should be less than 1% to avoid cracks at joints and ultimate failure in the walls. Tests on a number of commercial brands showed that some of them expanded slightly if heated free of load, but this was reduced to zero if the brick were loaded to 2 psi. during the test.

Resistance to spalling is necessary in all brickwork that must resist temperature changes, and is especially desirable in settings which are in intermittent operation. Since one of the principal reasons for using insulating refractories is to bring a furnace up from cold in very short time, this matter of spalling has evidently been satisfactorily taken care of. Furthermore, satisfactory service is given in baffles which receive the direct blast of flame from gas burners operated with on-and-off control. The amount of spalling in a dense firebrick is usually considered to be in proportion to the amount of "glass" (highly siliceous material) which separates as a eutectic liquid above 2800° F. during the burning operation. The higher the alumina and the purer the refractory, the less of this glassy material in the brick, and the better it can resist sudden changes of temperature.

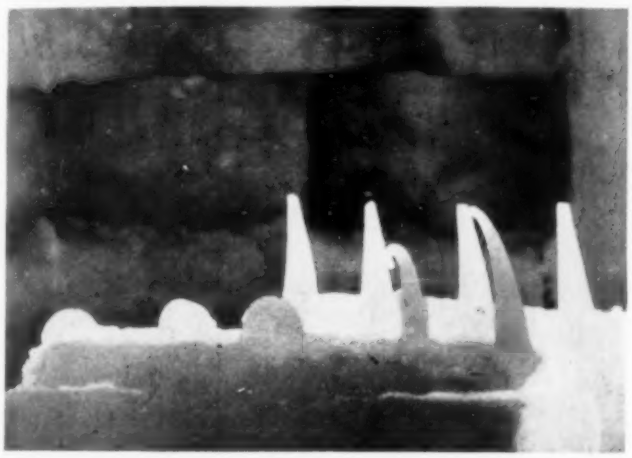
Physical strength at temperature is not as high as for dense firebrick, but if a self-supporting wall is under consideration, this is not so important, for the specific gravity of the material is so low. In large furnaces the weight is usually taken by an outer frame of structural steel. Probable safe operating limits at present are from 2100° F. to 2600° F., depending on quality; one manufacturer claims to make one grade of brick good for operation at temperatures under 3000° F.

Insulating capacity is about treble that of standard firebrick; thermal capacity is low. For that reason 70% of the time is saved from cold to heat, and walls of equivalent heat flow have a ratio of approximately one to ten in heat storage. While manufacturers' claims may not always be substantiated in practice, the best reports are that the following walls have equal heat flow: 36 in. of fireclay brick, 9 in. of insulating firebrick, and 4½ in. of insulating firebrick backed up with 1 in. of block insulation. Another estimate places the following walls on a par as to heat insulating value: (*a*) 18 in. of firebrick backed by 13½ in. of red brick; (*b*) 9 in. of firebrick backed by 4½ in. of diatomaceous insulating brick; (*c*) 9 in. of insulating refractory; (*d*) 4½ in. of insulating refractory backed by 2½ in. of diatomaceous slabs.



Press of the Type Used for Molding Insulating Brick and Semi-Refractories at Armstrong Cork & Insulation Co.

To counterbalance these advantages, there are some considerations as to first cost. Insulating refractories are rapidly destroyed in locations where slagging occurs, as the porous brick absorbs the slag and the brick disintegrates. Furthermore, the brick "dusts" somewhat, mostly in suspended arches where movements due to expansion and contraction cause the bricks to rub on each other. A cement coating will correct this in part (as well as its permeability to gases).



Hot Seger Cones — a Frame From a Movie Film Taken in Harbison-Walker's Laboratory

While some estimates might be presented, based on figures for heat absorption and transmission, it would be better to turn to actual furnace installations. Some figures are available on two annealing furnaces for seamless tubing operating at 1700° F., now walled with 4½ in. of insulating refractory, whereas they were formerly constructed of 6 in. of fireclay brick backed up by 4½ in. of insulating (non-refractory) brick. These furnaces are fired with natural gas, have combustion volumes of 1400 cu.ft. and 910 cu.ft. respectively. The longest cycle is 8 hr. heating to 1700° F. and cooling 10 hr. to 1200° F. When loaded to 138 lb. per sq.ft., the rebuilt furnaces used 1.97 cu.ft. of gas per lb. of metal as compared to 2.33 cu.ft. under the old conditions, a saving of 15%. When loaded more adequately (160 lb. per sq.ft.), the corresponding figures were 1.99 versus 2.65 cu.ft. of gas; and 25% saving.

In another very large, car-bottom type furnace for stress relieving, heating from cold up, 24% of the heat was required to heat the furnace, 29% to heat the metal charged, and 10% was radiated through the walls.

These figures indicate the great advantage in intermittent heating furnaces. If a quick cooling cycle is needed, auxiliary means must be used, for naturally radiation is slow. In heating furnaces in steel mills, where billets are brought to forging temperatures and furnaces operate on long campaigns, it is questionable whether insulating refractories will stand up. Reports are various about forge furnaces; some succeed and some fail. Doubtless this in part is due to the varying intelligence and care of workmen and foremen.

High Alumina Refractories

Turning now to heavy brick suitable for unusually high temperatures: It has long been known that the principal defects of fireclay as a high temperature refractory arose from the relative impurity of the raw materials. These combined at high temperatures to form low-melting silicates; as the amount of these silicates increased above the minimum necessary for a bond, the general excellence of the brick diminished.

Efforts of brick makers, therefore, have been directed toward securing the purest and most uniform clays. In one notable instance kaolin, the clay required for the finest white chinaware, has been used for raw material. Total oxides (other than silica and alumina) are less than 2.5% as compared with 3½ to 6% for the high grade fireclays. Kaolin brick may logically be classed as a high alumina refractory, and it is an attractive development, for the manufacturing technique need not be materially changed from that when ordinary fireclays are used, and the bricks themselves have a familiar look and feel to masons.

Many manufacturers are producing so-called diaspore refractories. Diaspore, the mineral, is hydrated alumina, but the principal sources are the clay beds of Missouri, where the diaspore is entangled with more or less clay. After calcining and firing the composition of the diaspore refractories therefore varies from 60 to 80% Al_2O_3 — usually it is about 70%. The alumina slowly changes to corundum at very high temperatures, but the characteristics of this type of brick are dependent mostly upon the nature and purity of the clay with which the diaspore is mixed.

Other manufacturers use sillimanite as raw

material. This mineral, when pure, has the chemical composition $SiO_2 \cdot Al_2O_3$. It changes slowly into another compound called mullite ($3Al_2O_3 \cdot 2SiO_2$) at temperatures above 2800° F., with the formation of some highly siliceous glass, but the space lattices of the two are so similar that the crystal "skeletons" of the mullite are the same size as the original sillimanite. Thus the viscous silica which separates is contained within the new crystals and does not cause the brick to soften until greatly overheated. Mullite is the only silicate which is stable between 2800° F. and 3300° F.; above that temperature there is a slow conversion into the two constituents, solid corundum (Al_2O_3) and glassy silica. (Mixtures of alumina and silica compounded to make an artificial mullite have also been melted in an electric furnace and cast into brick shapes.)

Kaolin refractories have been very successful in heat treating and forging furnaces, malleable iron furnaces, enameling and pottery kilns. In the ceramic industry they are particularly suited for a combination of high heat from all sides and load, such as for piers.

Diaspore bricks are favored for lining rotary kilns used in the cement, dolomite, and lime industries, on account of the ease with which they accumulate a self-healing coating of slag. In the metallurgical industry they have successfully competed with high grade fireclay brick in drossing furnaces for lead, and also in brass melting furnaces.

Sillimanite bricks have given good service in firing tunnels for oil and gas flames, forging furnace walls and roof, and in electric furnaces used for such purposes as the melting of brass, gray iron, and steel.

Refractory Cements and Ramming Mixes

Some recent notable improvements have been made in refractory cements for laying up or patching furnace walls, and ramming mixes for patching or making entire linings. A strong air-setting cement is especially useful in bricklaying, to replace the slurry of ground brick (plus a little clay) which has been the traditional material.

Much stress is laid on correct grain size analysis of these cements; frequently the "wet pan" is discarded and the fine dried materials mixed by tumbling in a way to avoid further grinding action. Calcined chromite, diaspore, mullite, and silicon carbide are the usual basic raw materials, depending upon the service required. The prior heating of the diaspore to convert it into minerals stable at high working temperature is, of course, a prime consideration. A minimum of plastic material is then intimately mixed; it is as nearly as possible of the same chemical nature as the grains. Many of these slightly moistened mixtures will air-set over night; others are strongly tamped dry and sintered in place by a wash heat.

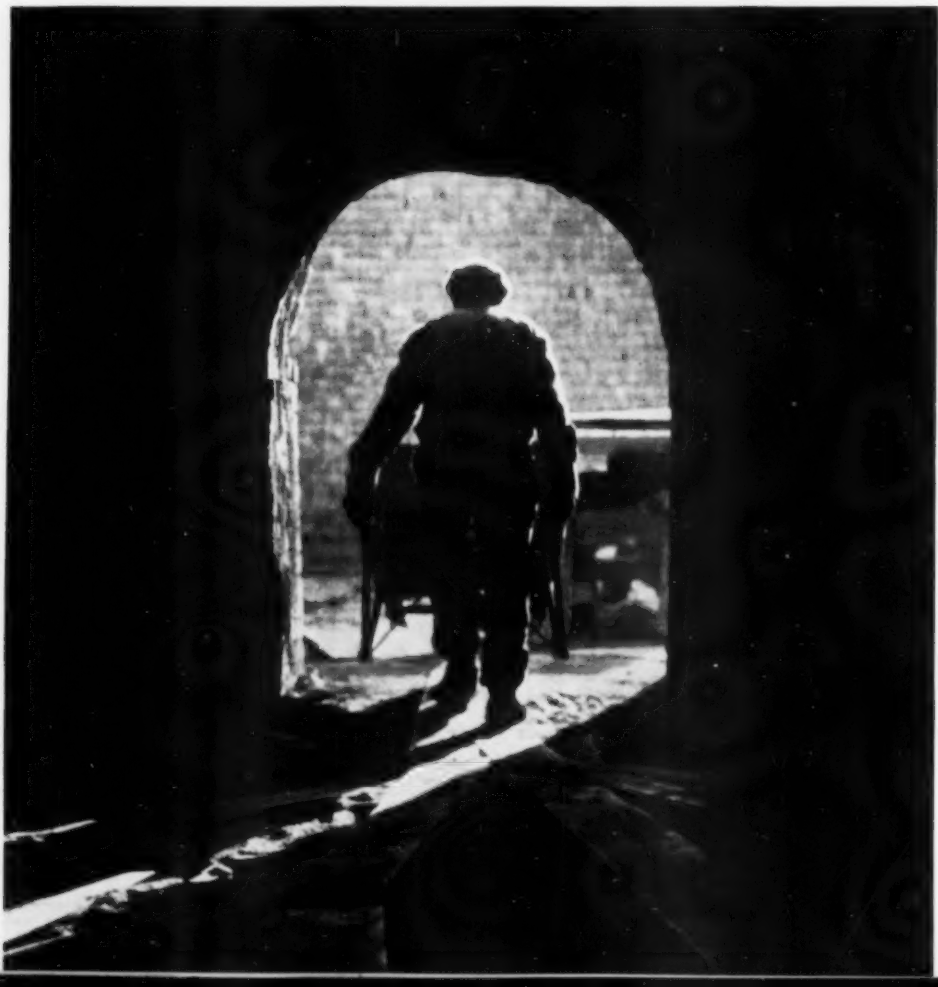
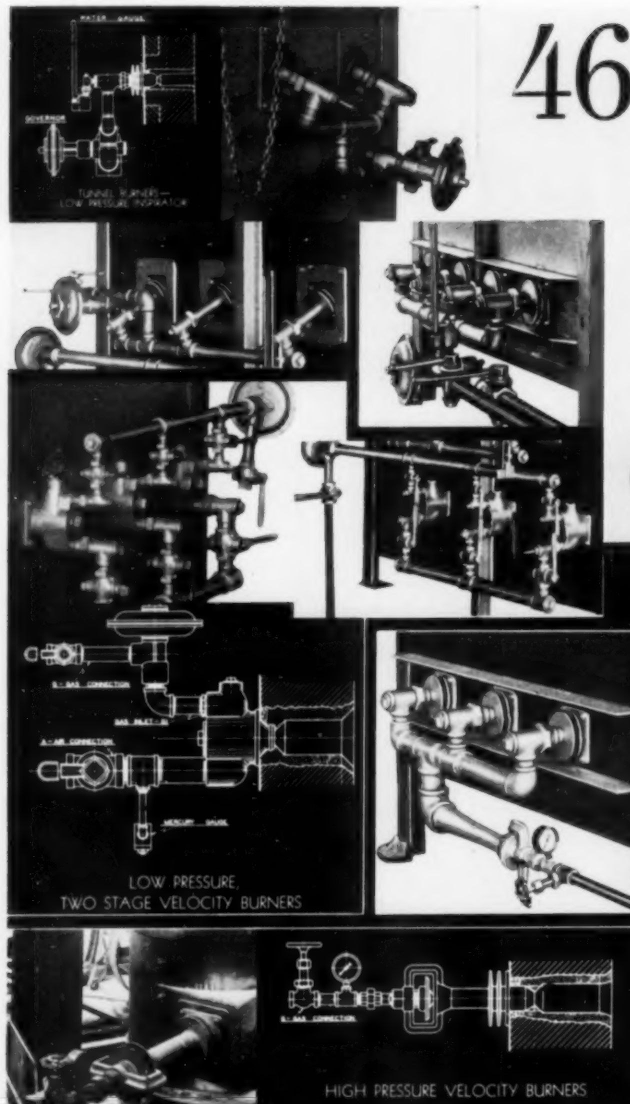
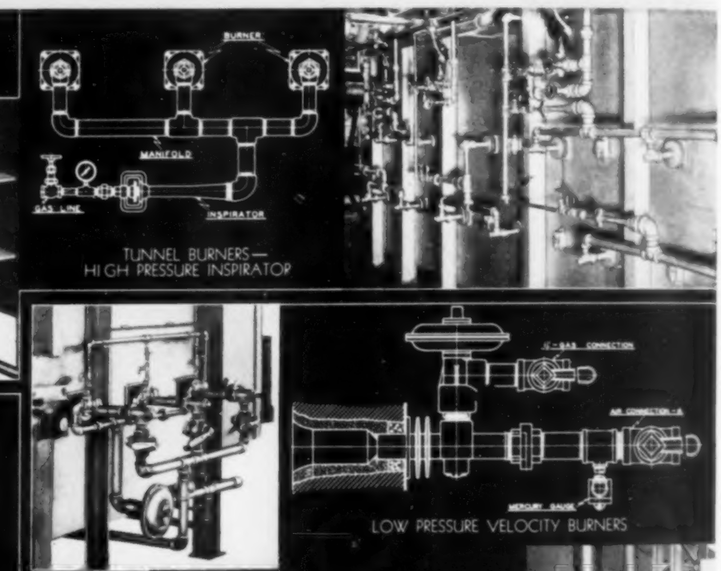


Photo by H. M. Mayer


TUNNEL BURNERS—
LOW PRESSURE INSPIRATOR
GOVERNOR
LOW PRESSURE,
TWO STAGE VELOCITY BURNERS
HIGH PRESSURE VELOCITY BURNERS
HIGH PRESSURE, TWO
STAGE VELOCITY BURNER
HIGH PRESSURE, TWO STAGE
VELOCITY BURNER—WALL ADAPTER


BURNER
MANIFOLD
GAS LINE
INSPIRATOR
TUNNEL BURNERS—
HIGH PRESSURE INSPIRATOR
LOW PRESSURE VELOCITY BURNERS
HIGH PRESSURE, TWO STAGE VELOCITY
BURNER—WALL AND ANGLE BRACKET
DIFFUSION
COMBUSTION
BURNER

ANNEALERS

(Continued from page 72)

a "replacement" instead of cast iron or steel covers. Sheets annealed in a pile also come out fairly flat; while an absolutely bright anneal is seldom effected, this is of small moment for such things as tin plate, which must apparently be pickled anyway to produce a slight surface roughness or "tooth" for the metal coating to adhere.

Continuous Normalizers

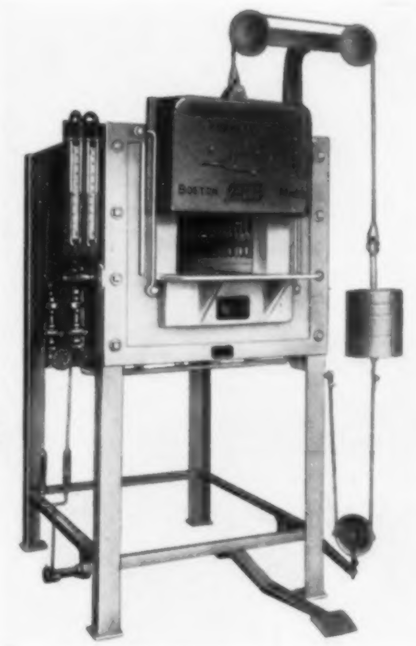
Continuous normalizing of steel sheet was well established some years ago. Its advantages, both in the realm of economics and metallurgy, for deep drawing sheet are so well known that they do not need to be repeated here. Bright normalizing in tonnage is a matter for the immediate future. No large installation has yet been made, for the steel mills profess to be interested, not in a battery of small furnaces, each capable of about a ton an hour (which can probably be built and guaranteed now), but in a single large furnace for the entire mill's production, wide enough for the widest sheet yet proposed. Obviously it will be quite a problem in design and construction to make such a large gas-tight furnace with a roller or walking beam hearth, heated with electrical resistors (or with gas around a muffled working chamber), because the infiltration of a small fraction of 1% of air would oxidize the material under treatment during the cooling cycle. The advantage of such an installation will obviously be the production of bright sheet which will require no pickling.

IF YOU WANT MODERN FURNACE EQUIPMENT

"AMERICAN"
Electric Furnaces

JUTHE
Gas Furnaces

HB-10 HIGH SPEED FURNACE
(With Atmospheric Control)



B-20 PRE-HEATING FURNACE
(With Atmospheric Control)

NA-21 AIR TEMPERING FURNACE

FOR

Air Tempering
Air Superheating
Annealing
Aluminum Melting
Brass Holding
Carburizing
Cyaniding
Drawing
Forging
High Speed Hardening
Lead Hardening
Nitriding
Normalizing
Oil Tempering
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ALUNDUM REFRACTORIES

For Enameling Metal

Whether you are enameling cast iron or steel — in box furnaces or continuous furnaces — you'll find that Alundum Refractories (fused alumina) have just the right characteristics:

Resistance to high temperatures.
Great strength.
High heat transfer.
Stability.
Long life.
Low fuel cost.

CRYSTOLON REFRACTORIES

For Heat Treating Metal

In many types of heat treating furnaces you'll find Crystolon Refractories (silicon carbide) meeting exacting requirements. They are popular because of these features:

Resistance to high temperatures.
Great strength.
High heat transfer.
Resistance to spalling.
Resistance to abrasion.
Long life.
Low fuel cost.

MAGNESIA REFRACTORIES

For Melting Metal

In all types of induction furnaces — large and small — for melting ferrous and non-ferrous metals — Norton electrically fused magnesia refractories are widely used. Available in the form of cements and bonded shapes — in different mixtures to meet different conditions. Their special features are:

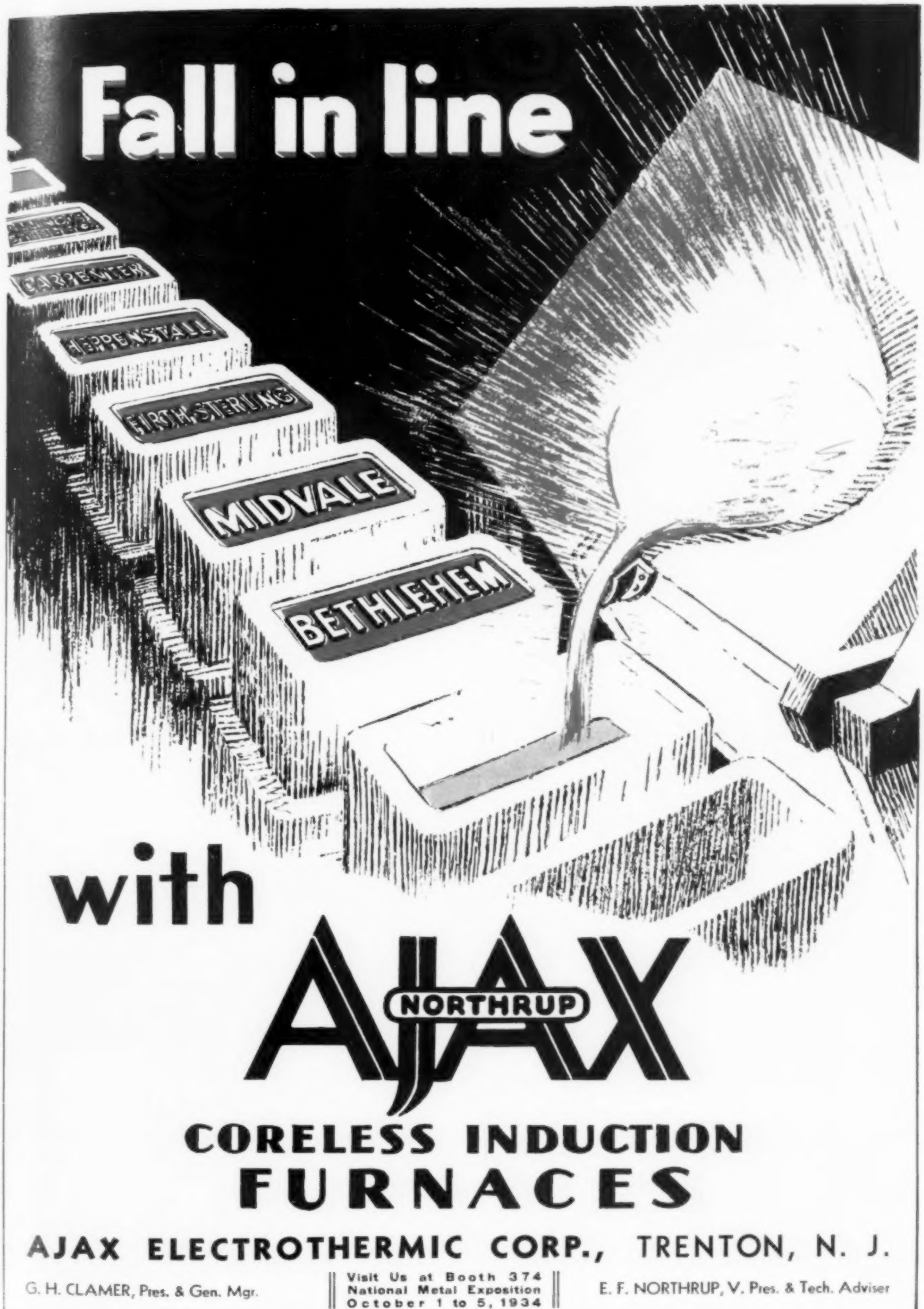
Resistance to high temperatures.
Chemical resistance and low permeabilities to molten metals and oxides.

NORTON COMPANY, WORCESTER, MASS.

NORTON

NORTON REFRACTORIES

Continuous Non-Oxidizing Annealing Furnace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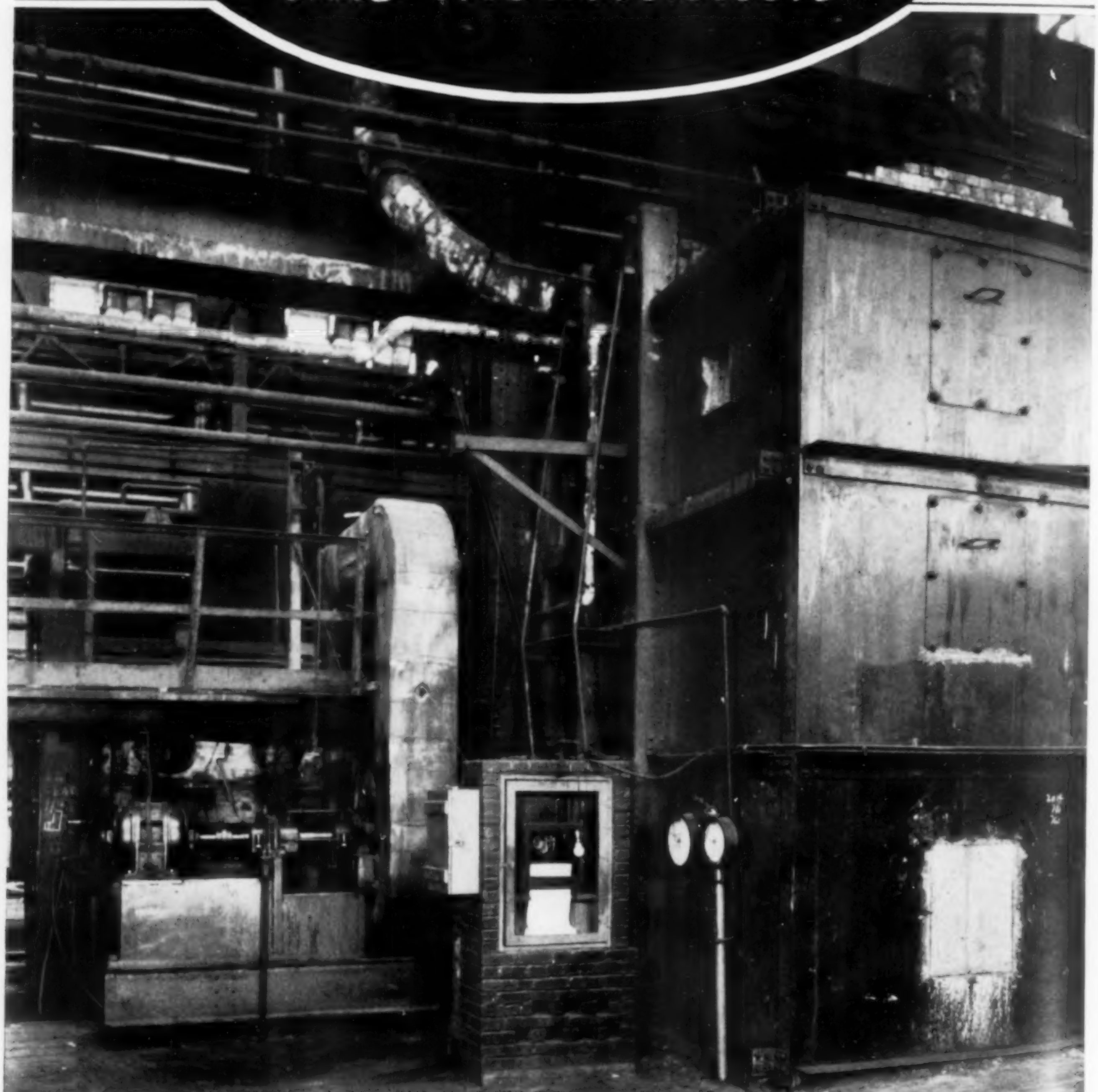
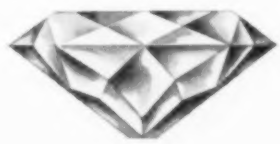
FUEL SAVINGS
easily justified this installation



Recuperator applied to Four-Door Reheating Furnace—Note "hot" fan handling air at 900° F.

for shaping and conditioning hard cemented carbide tools



IT'S MADE OF CRUSHED DIAMONDS!

CARBORUNDUM Research Laboratories announce a new wheel made from genuine, crushed South African Diamonds—a wheel that through long exhaustive tests has shown startling results in grinding hard cemented carbides.

On pure cemented carbides this new wheel is approximately thirteen times faster cutting—removes thirteen times more stock per minute than previous specially developed abrasive wheels.

In the grinding of mounted tips—that is grinding the cemented carbide as well as the steel tool stock—the new Diamond Wheel shows four times greater stock removal per minute.

The diamonds used are small South African gems too small and off-colored to be considered precious. They are crushed—accurately graded to comparatively coarse, 90 grit; the fine, 220 grit; and extra fine, 400 grit—and bonded with a special bond developed in our laboratories. The result is a wheel that cuts with astonishing speed.

The new Diamond Wheels require no dressing—in fact, it is impossible to dress them. The thousands of tiny diamonds that stand out like so many miniature cutting tools do not break down or crush. They stay permanently sharp precluding the need of dressing—even if it could be done.

These wheels are made to micrometer exactness—balanced to within a fraction of a gram. The new wheel is used with water—wet grinding—and it produces clean, true, straight, un-nicked edges and truly flat tool faces—beautifully finished. Overheating is eliminated—in grinding, the tools aren't even uncomfortably warm.

It is important to note, that by finishing with the fine grit wheel, the long, tedious, costly operation of lapping is eliminated.

Indications are that the Diamond Wheel can be effectively used also in many and various fields on materials approaching in hardness the cemented carbides. Studies of these applications are now being made.

Limited stocks are now available in six and seven inch diameter wheels in the three grits.

Again Carborundum makes an important contribution to industry.

THE CARBORUNDUM COMPANY

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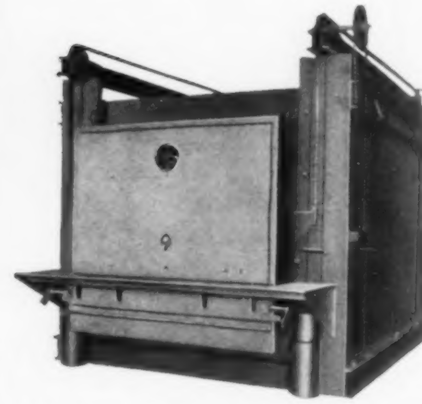
Niagara Falls, N. Y.

Canadian Carborundum Co., Ltd., Niagara Falls, Ont. Sales Offices and Warehouses in New York, Chicago, Boston, Philadelphia, Cleveland, Detroit, Cincinnati, Pittsburgh, Milwaukee, Grand Rapids; Toronto, Ont. (Carborundum is a registered trade-mark of The Carborundum Co.)

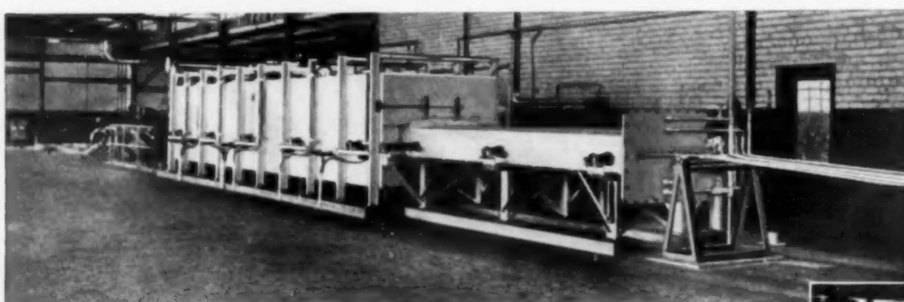
Your EVERY Need

from

Electric-furnace brazing lends itself admirably to continuous production. These mesh-belt conveyor furnaces are used for copper-brazing refrigerator condensers of the steel-fin type. Handling costs are low; economy is good; temperature, time, and atmosphere are under accurate control

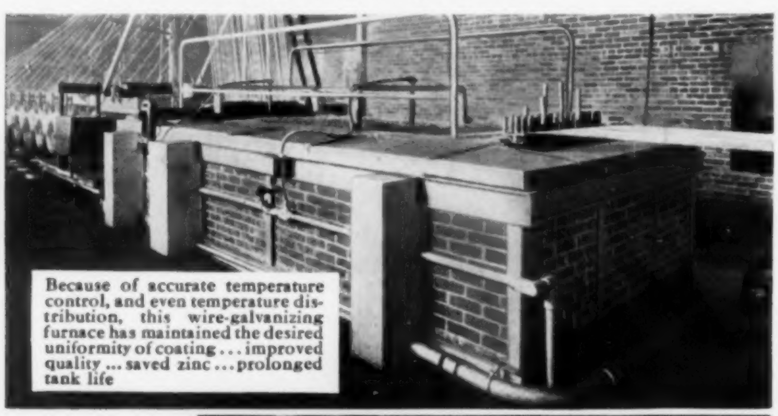


One of the standard box-type furnaces of the extensive G-E line. Other standard G-E types include belt-conveyor, rotary-hearth, car-bottom, air-draw, and elevator furnaces



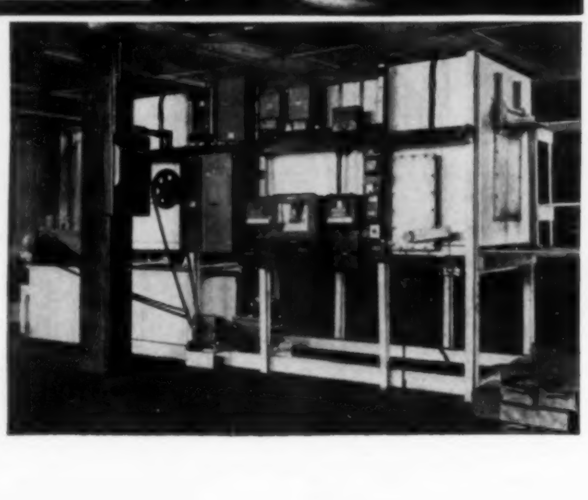
Continuous, roller hearth electric furnace used to anneal steel strip. One of many installations for which controlled atmospheres of any desired analysis, either oxidizing or deoxidizing, are produced by G-E combustion-type furnace-atmosphere controllers

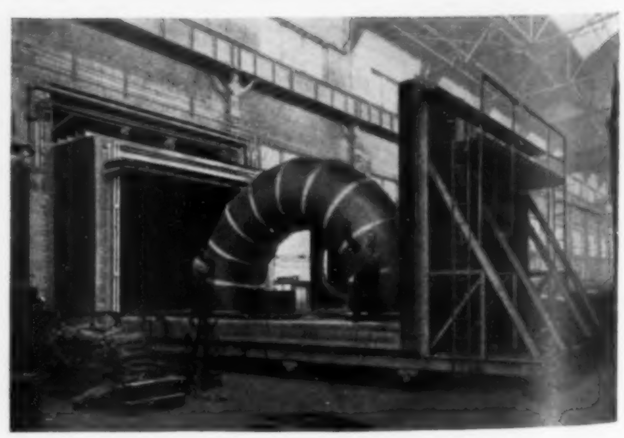
Below—By paying for itself in a year, this pusher-tray-type G-E electric furnace demonstrated its ability to cut over-all costs. Used for bright-annealing steel punchings. A G-E ammonia dissociator supplies the atmosphere



Because of accurate temperature control, and even temperature distribution, this wire-galvanizing furnace has maintained the desired uniformity of coating ... improved quality ... saved zinc ... prolonged tank life

Right—This G-E plate-belt conveyor furnace is actually a hardening machine. The parts are self-quenched from an accurately maintained temperature and automatically delivered from the quench tank. Adjustable-speed drive provides flexibility in heating time. The controlled atmosphere reduces decarburization, prevents scaling, and minimizes cleaning costs





The even temperature distribution throughout this 2000-kw., car-bottom type G-E electric furnace assures proper, *uniform*, annealing of large castings and fabricated shapes weighing up to 75 tons

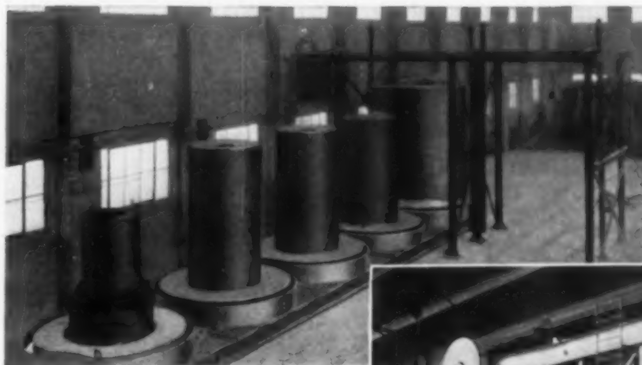
in Electric Furnaces ONE Manufacturer

THE expense-saving performance of G-E electric furnaces is a natural result of the background from which the now extensive G-E line was developed — a background of practical experience acquired in solving the complex industrial-heating problems in General Electric's own factories—a background that requires these furnaces to *pay their own way* under actual operating conditions.

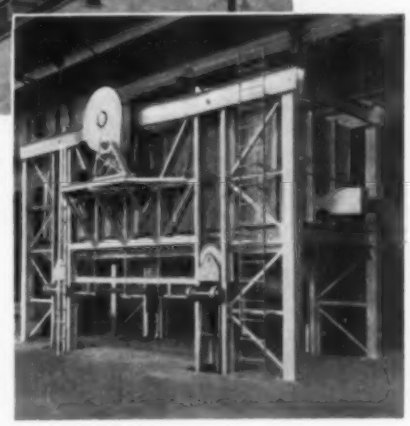
G-E electric furnaces reduce handling charges' simplify processes, eliminate retreatments, increase uniformity, provide better working conditions, and improve quality—factors that produce substantial savings in total production cost.

What's more, you can duplicate these profitable results in your own plant, for G-E electric furnaces are available in sizes and types that meet the requirements of every industry. The *complete* G-E line—with G-E control built to match each type—enables you to entrust *one* manufacturer with the undivided responsibility for your *every* need in electric furnaces.

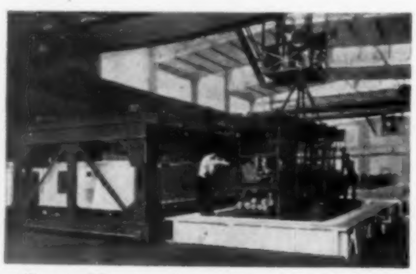
For information, write the industrial heating specialist at the G-E office nearest you; or address General Electric, Dept.6A-201, Schenectady, N. Y.



"Our four G-E bell-type furnaces for annealing coiled steel strip", writes the Thompson Wire Company of Mattapan, Mass., "have reduced our annealing cost 10 to 20 per cent. In fact, the furnaces will pay for themselves in less than three years"

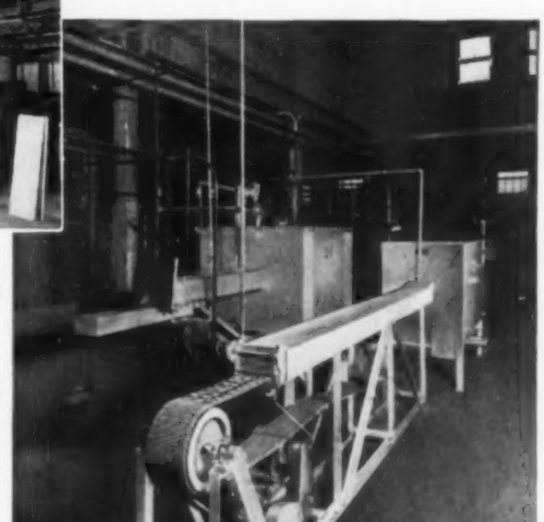


Right — Improvements in controlled cooling and controlled atmospheres are features of this G-E elevator-type annealing furnace. In it, you can anneal, without oxidation, steel sheets, strips, bars, punchings, etc. — using high or low rates of cooling as desired

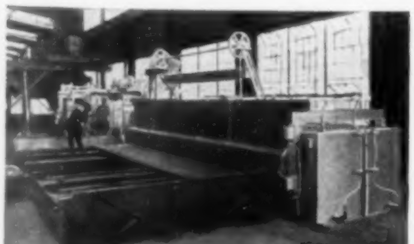


Alloy-steel bars can be no better than their heat-treatment. These two G-E pit-type annealing furnaces are used in the production of bars that are so well and so accurately heat-treated as to develop their full "physicals"—bringing out their high inherent quality

This G-E continuous, heat-sealed enameling furnace has reduced handling costs, has speeded up production, and has operated without shutdown for repair for nearly four years—in the Enamel Products Company plant, Cleveland, Ohio



Right—For high-quality bright-annealing of punchings, stampings, tubing, and flat strip, or for electric-furnace brazing, this G-E mesh-belt conveyor furnace performs like a production-line machine, maintaining a flow of output both continuous and uniform. A G-E combustion-type furnace-atmosphere controller is used



Left—Full-automatic timing of sequences for preheating, heating, and quenching is provided by this unusual double-chamber G-E roller-hearth furnace—used for normalizing or hardening alloy- or carbon-steel bars—adjustable for various sizes of stock

170-14

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Lower in price,

COMPARATIVE OPERATING DATA

	FIREBRICK LINING	B&W IFB LINING	SAVING
Time from lighting until ready for work	60 min.	10 min.	83.3%
Fuel consumed during this period	1,250 cu. ft.	200 cu. ft.	84.0%
Fuel consumed during operation	10,105 cu. ft.	8,694 cu. ft.	14.0%
Amount of stock per square foot of hearth	53.7 lb.	83.4 lb.	55.3%
Total weight of stock heated	1,610 lb.	2,496 lb.	55.0%
Gas consumed per pound of stock heated, including heating-up	7.5 cu. ft.	3.57 cu. ft.	52.4%

yet

too, will save 50% of your industrial furnace operating costs daily

The remarkable reductions in operating costs that have been secured through the installation of B&W Insulating Firebrick are now extended to those operating industrial furnaces in the lower temperature zones *at a new low initial cost* through the development of the B&W K-26.

This new insulating firebrick is substantially lower in price than the original B&W Insulating Firebrick, yet retains every characteristic requisite to lower operating costs in industrial furnaces operating at temperatures under 2600 degrees fahrenheit.

For service at higher temperatures, The Babcock & Wilcox Company has perfected the B&W K-30, which attains its maximum use limit at 3000 degrees fahrenheit. Both of these insulating firebrick not only possess every advantage of an efficient insulator, but, due to their high fusion points, freedom from shrinkage, and inherent ability to support loads, may be used as a refractory in the furnace structure directly exposed to heat, thereby decreasing the heat storage as well as the heat flow.

These features result in time and fuel savings sufficient to warrant your thorough investigation. Write for *Service Reports* . . . even the briefest examination of these records will prove the adaptability of these refractories to your particular requirements and will indicate the amount of savings you, too, may secure.

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R-23

HEAT TREATING and FINISHING, METHODS and SUPPLIES . .

● Heat treating in controlled atmosphere is a development that includes things as different as scale-free tools, carburized gears, and nitrided pins . . . . Considerable progress is also noted in solid carburizers . . . . Quenching salts and quenching baths have been improved, and an understanding gained of the excellence of parts, deep hardened by quenching in hot baths . . . ●

REVIEW OF . . .
HEAT TREATING
AND FINISHING

By C. R. Austin
Consulting Metallurgist,
State College, Pa.

THERE are but few metal products on the market which have not been subjected to some form of heat treatment or some finishing operation. Moreover, the term "heat treatment" has lately been expanded to include the surface conditioning of metals as well as the modification of the structure and physical properties of the alloy.

Interesting recent developments are in the use of controlled atmospheres to bring about some required surface condition of a metal or alloy. Such is the case in bright annealing, gas carburizing, nitride hardening, and in the heat treatment of tool steels and gears without surface damage. Considerable attention has also been devoted to solid carburizing, liquid cyanide hardening, quenching methods and quenching oils, age hardening, malleableizing, and methods of cleaning and surfacing the finished product.

Bright Annealing — In the review of the furnace industry (page 67) considerable attention has been devoted to the general problem of bright annealing ("bright" being a term whose meaning is dependent largely on the product under consideration). A trend in this field is toward the use of high purity gases in a closed atmospheric cycle with a purification plant.

Close control of the gas is necessary when annealing low carbon steel to a mirror finish, silicon steel for its magnetic properties, and heating brass without discoloration. It has been demonstrated on a laboratory scale that stainless steel can be completely bright annealed in this manner but the conditions required are extremely rigorous.

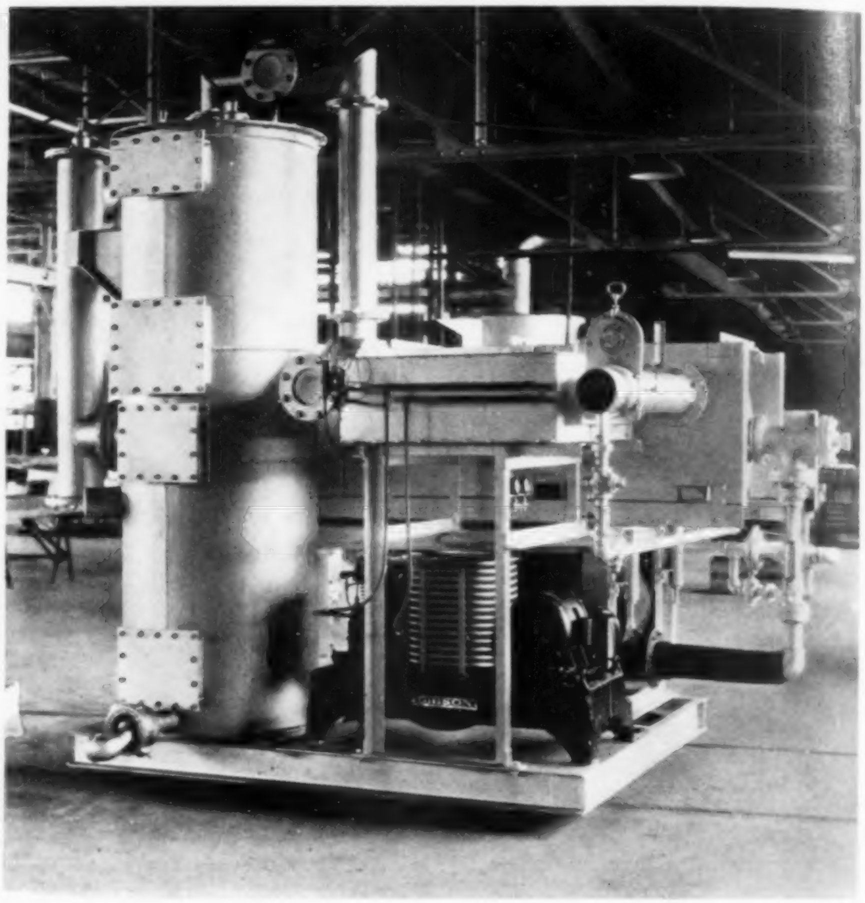
The surface condition of the charge when introduced into the furnace is important. Thus, annealed cold rolled low carbon sheet has come mirror-bright from batch-type electric furnaces after the oil retained from the cold rolling was changed to suitable composition (mineral oil) and free from extraneous material.

Ordinary "bright anneal" of mild steel and copper is relatively a simple operation. Embrittlement of copper by hydrogen is completely eliminated by using the recently developed oxygen-free copper.

In this section may be mentioned the new use of hydrogen or dissociated ammonia containing only a trace of water vapor in the non-decarburizing anneal of high carbon steels. This subject is to be discussed in a paper at the New York convention of the Society. A cross-section of a cracking unit for dissociating ammonia is shown on page 70.

Various Heat Treatments — In many instances where continuous normalizing is the object, slight discoloration of the surface is of little moment. Work of this nature accumulates

experience in design, in the form of smaller furnaces installed in fabricating plants. A bolt manufacturer, for instance, has a small continuous furnace for bright heat treating Class III bolts, to exacting specifications for size and physical properties. These bolts used to be box annealed in charcoal to avoid scaling. Now they are heated to temperature in an atmosphere which prevents scale, quenched through a submerged outlet into oil, and drawn in a corresponding atmosphere. The result is that the threads retain their shape and size to 0.001 in. There is a slight loss in carbon — a matter which is mitigated by rapid work (short time at heat) on mild or medium carbon analyses. Another atmospheric adjustment produces a blued surface, sometimes bought because of its corrosion resistance.



Gas Preparation Unit of 8,000 Cu. Ft. per Hour Capacity to Provide Correct Atmosphere for Battery of Box Annealers at Empire Steel Co. Sheet Mill

Brief reference must be made to developments in short cycle malleableizing. More information is accumulating on the relationships between superheating in the melt, chemical composition, and heat treatment. By the use of controlled atmosphere scaling is prevented, and the absence of packing speeds up the operation and the thermal efficiency. Bell-type furnaces for short cycle malleableizing are now available to take charges from 1000 lb. and upwards, and cycles as short as 48 hr. have proved industrially satisfactory.

Gas Carburizing

Primarily gas carburizing aimed to reduce the time necessary for the required high carbon case. However, important collateral advantages may accrue when the surface of the work is kept clean and even bright, and the maximum carbon concentration on the surface controlled.

While these matters are usually thought of in relation to the case hardening of objects to resist wear, carbon control has an important application in the final heat treatment of medium and low carbon steels, where a decarburized skin is unacceptable. Thus, normalized low carbon sheet is believed difficult to galvanize with a "tight coat" on this account. Bright normalizing of sheets, when it comes, will not only avoid final pickling operation, but at the same time put back into the surface of the steel the small amount of carbon required for successful galvanizing. This has already been effected in a small way under conditions simulating continuous annealing within a period of less than 5 min.

Gas carburizing has received the attention of inventors and metallurgists ever since it was established that some gas was a necessary carrier of carbon from the packing to the work. It is necessary to make only brief reference, especially since H. W. McQuaid published an article in the July issue of METAL PROGRESS on shop practices. He appraises it as one of the simplest heat treating processes, enabling the metallurgist to produce cases of any desired characteristic as

long as two important factors are followed: Uniform temperature and satisfactory carburizing gas. It is apparently only necessary to dilute a rich carbonaceous gas with a weaker gas (such as flue gas) to arrive at a commercial carburizer which is practically fool-proof.

Considerable success has also been had with batch-type furnaces where a heavy oil is dripped into the hot chamber, there to be gasified and circulated vigorously through the charge by means of a fan.

Continuous gas carburizers have been installed at various units of Chrysler Corp. for such parts as steering sectors and steering worms, free wheeling drive shafts and camshafts. Work loaded in trays is pushed slowly through a muffle with air locks on each end. Carburizing gas enters with the cool work and both progress through zones of rising temperature. Upon entering the gas breaks down partially into its constituents, and the work is covered with a light deposit of carbon. As the work and gas move along to a hotter region (1650° F.), the carbon dioxide becomes an active carrier of this carbon and it enters the steel surface rapidly. Finished work comes out scale-free, but blue or black in color.

Solid and Liquid Carburizers

Sentiment among metallurgists in the automotive industry appears to be that gas carburizing is to be the next change in heat treatment departments where they have enough production so that furnaces can be adjusted to single parts, or to a few similar shapes. Replacement of existing types of continuous counterflow furnaces using pots and solid carburizers will have to be warranted by saving in supplies and equipment, savings in labor for packing the boxes and handling them and the carburizer, and a heat saving in a reduction of gross material being heated.

Enthusiasm for a new development should not make us lose sight of the fact that the pack hardening process is still the one which is carburizing the parts! With proper steel, a uniform, well made compound, proper furnace and box equipment, and good pyrometer control — all of which having been developed to a high degree of excellence — accurate results in depth and carbon content can be obtained by simply running on a time and temperature cycle.

Competition from a new process will also incite the promoters of the older methods to study and improve their product. The comparative excellence of today, in relation to a decade ago, is no indication that the limit of efficiency of solid carburizers has already been attained. Auxiliary improvements have been made in special carburizing boxes, closely conforming to the shape of the work and holding a minimum of compound. Production of steels which resist grain growth to very high temperatures may also permit the use of correspondingly high temperatures in carburizing, and an associated saving in time. Some data are available to indicate that powdered ferrosilicon, incorporated in the granules of carburizer, prevents the hyper-eutectoid cases which otherwise result from high carburizing temperatures.

Some interesting studies on the nature of the cyanide case and the desirable bath compositions have been printed by D. A. Holt in METAL PROGRESS in October, 1931. He finds that the various S.A.E. alloys absorb considerable nitrogen but relatively little carbon; this occurs very rapidly, even in 15 sec. This nitrogen is held in the surface layer within a few thousandths of an inch, and he believes that it is responsible for the characteristic wear resistant surface. At any rate, gear

makers are almost unanimous in their belief that oil quenched gears should preferably be quenched from cyanide. An almost infinite variety of parts made of screw machine stock, low carbon steel, and medium manganese steel are held in molten cyanide for a proper time and quenched to develop a hard and wear resistant surface.

New liquid carburizers are on the market which are said to introduce carbon, without nitrogen, into the steel at a very high rate — acting in one-third the time required for pack hardening. An essential feature of one of these is a compound containing amorphous carbon which floats on the surface of the bath, protecting it from oxidation. Such rapid baths should not deteriorate with use, and should be capable of "sweetening" by minor additions — this is where rapid carburizers, promoted in the past, have failed.

Outlook for Nitriding

Nitriding, the production of a hard surface by heating steel at moderate temperature in ammonia, was the topic of the hour in 1930. At that time it seemed that the economies inherent in a non-warping, low temperature heat treatment, without quenching, would result in its widespread adoption for wear resistant parts, especially since the hardness of the surface was so great as to be virtually unmeasurable with standard test apparatus.

As so often happens, rosy anticipations were unfulfilled; in production some matters arose which were not so favorable. In the first place, the atmosphere is too expensive to waste, and trouble was experienced with the high alloy containers. Furthermore, the best surface conditions were attained by a patented alloy steel which did not match the numerous other manufacturing qualifications of the familiar S.A.E. steels. These problems are being surmounted, and studies indicate that ordinary steels and even some of the cast and malleable irons, can be successfully nitrided to a glass-hard surface, so it is reasonable to believe that present uses will expand in the future, somewhere approaching the popularity of the process in Europe.

Meanwhile two special processes have been patented and exploited. One subjects ordinary low carbon steels to active nitrogen led into a salt bath, followed by quenching. The second process subjects the molybdenum, chromium, or chromium-vanadium steels to activated nitrogen at low temperature in a pressure-tight container, producing quickly a hard case without a quench.

Heat Treating Tool Steel

It has long been understood that atmospheric conditions must be controlled very accurately on account of the effect on the quality of carbon tool steels. The relation between these somewhat intangible matters is being indicated by data obtained in tests due to Vice-President Shepherd of the American Society for Metals on penetration-fracture and by Messrs. Luerssen and Greene on torsion impact. (The latter report that the correct drawing temperature for maximum toughness increases with increase of quenching temperature and decreases with increase in drawing time.)

The effect of various furnace atmospheres on the toughness of brittle timbre steels is very marked, while tough timbre steels are but little affected. "Timbre" is described by Mr. Shepherd as the inherent property of a tool steel independent of analysis, which influences the hardness penetration and width of allowable quenching range. It would appear that by such penetration-fracture tests we are on the point of getting some measuring stick for accurately appraising the performance of tool steels in severe service.

As regards high speed steel, studies by Sam Tour indicate that the microstructure is materially affected by the oxygen and carbon monoxide content of the furnace atmosphere during heat treatment. He believes that unless very careful *atmospheric* control is obtainable, 2400° F. is too high for hardening; 2360° F. is better for the furnace atmospheres commonly met. Hardening from the higher temperature in controlled atmosphere undoubtedly produces a better tool, as far as the cutting properties are concerned. This fact is of special value in formed tools like milling cutters.

In recent years there has been a rational adaptation of the tool maker's "reducing atmosphere" (fuel gas burned with insufficient air) to modern practice on high speed steels, carbon steel tools and die steels. Such tools are satisfactorily heated in a hearth furnace, heated with silicon carbide rod resistors, or in muffle furnaces externally fired with gas. In any case a measured amount of correct gas-air mixture is introduced into the furnace near the door, filling it with a reducing atmosphere and protecting the work from an inrush of air when the door is opened.

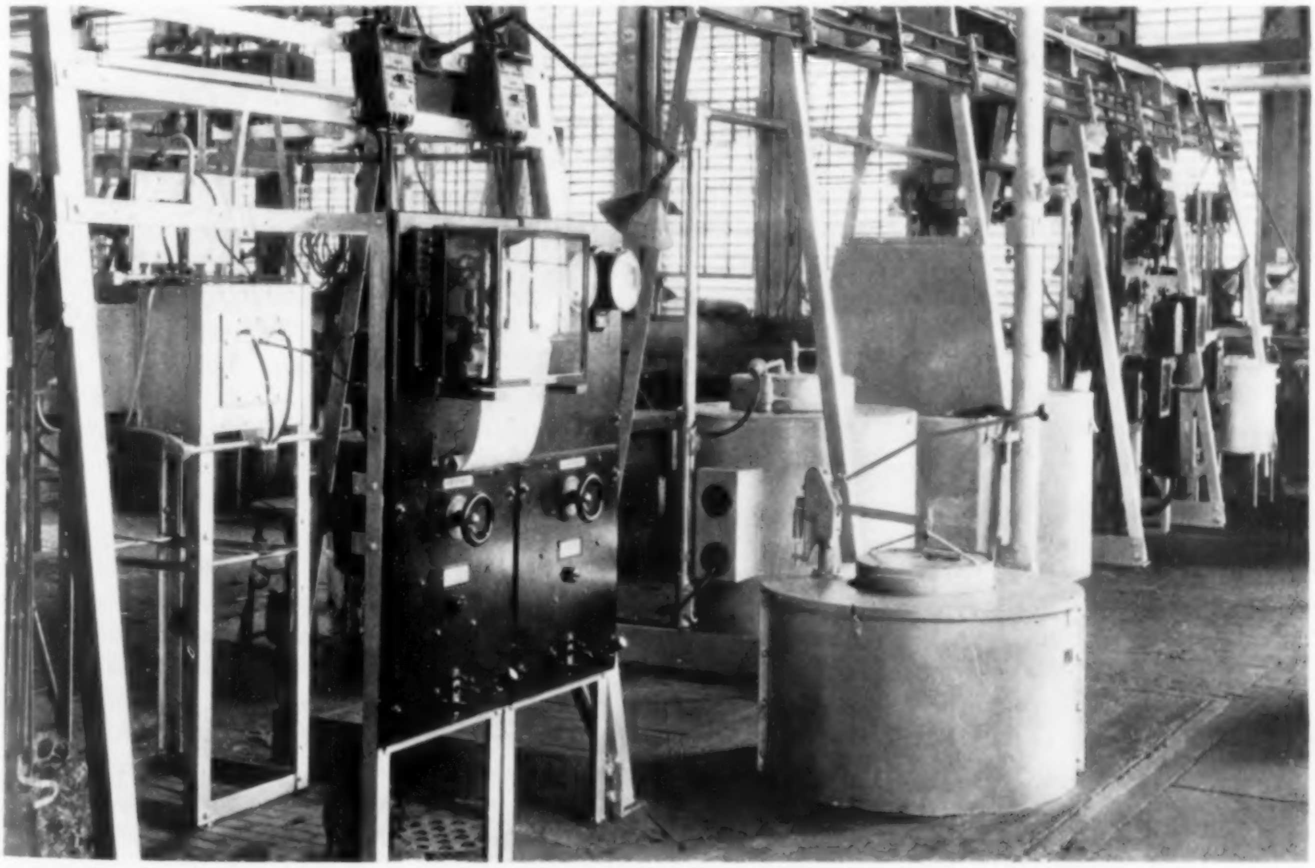
These furnaces were proposed primarily to

control the amount of scale, but it appeared that high speed steel so heated resisted grain coarsening due to overheating. One so heated makes a better all-round tool than one heated an equal time and just as hot in a scaling atmosphere. This inhibition of grain growth is probably due to carburization of low carbon regions in the steel, dating back to the ingot, thus removing or suppressing the gradients in composition which promote rapid grain growth.

Another batch-type of furnace, for carbon steel tools and dies, which is finding favor, is adapted from a well-known method of hardening to give the workman triple control of furnace atmosphere, rate of heating, and quenching temperature. This method of heat treatment depends on quenching from the proper temperature as related to the critical point, measured as the steel is being heated for quenching. To it has been added a cracking unit for introducing a carbonaceous gas into the chamber, and a definite program control for rate of heating. This prevents scaling, pitting, and decarburization of the steel; correct heating rate also minimizes the amount of dimensional change and warpage.

A new bell-type retort furnace has flexibility of use as the main feature, since it may be adapted for carburizing, nitriding, hardening, normalizing and tempering. Another batch furnace has an oil vaporizer attachment, which converts oil fuel to gas fuel, for more accurate regulation at the burner.

Completely distinct from the above heat treating equipment is a new gas-fired continuous furnace for heat treating in a gas atmosphere. This is also a multi-purpose furnace, since any desired atmosphere can be carried in the muffle. A reciprocating hearth may be flat or grooved to the work; it acts as a conveyor itself, inside the furnace at all times and therefore heated only once. When a continuous operation is desired, the forward stroke of the hearth is interrupted suddenly, and the work advances jolt by jolt through the furnace by its own momentum. For quenching, work is discharged through a chute, sealed in the quenching fluid.



Pyrometric Control and Record Is a Prime Requisite of the Modern Heat Treating Plant. View taken at Brown & Sharpe, Providence, R. I.

Quenching Methods

In heat treating for annealing or softening, the resulting structure depends largely on the way in which the steel is heated, on the maximum temperature utilized, on time at temperature, and on the nature of the surrounding atmosphere. However, where the work is to be hardened, the quenching operation may play an equally important role in modifying the final structure. It is therefore to be anticipated that investigators are continually analyzing the effects of modified forms of quenching on the properties of the hardened part and studying the nature of the hardening process.

An excellent correlation on the mechanism of heat transfer on quenching is given by Howard Scott in the July *Transactions* of the American Society for Metals. He shows that cooling, during quenching in liquids, progresses in three stages distinguished by the mode of heat transfer from the metal surface to the surrounding material.

Particular attention has been focused on the effects of modified forms of quenching on the structure and physical properties, by the remarkable series of papers published by E. C. Bain and his collaborators in United States Steel Corp. Research Laboratories. These papers deal essentially with the *rates* at which austenite transforms into ferrite and carbide at temperatures underneath the critical point, and with the effects of this delayed transformation on the properties of the steel.

In an article by H. Diergarten and another by H. L. Daasch, published in METAL PROGRESS last year, information is available on what has been termed "graded hardening" or "interrupted hardening." Diergarten, writing from Germany, quotes some studies on a nickel-chromium steel (approximately S.A.E. 3340) cooled fairly rapidly down to various sub-critical temperature zones — where austenite transforms into pearlite, martensite, or an intermediate structure — and holding there for various periods before further cooling or reheating. On the basis of his results, graded or interrupted heat treatments are recommended according to one of three structural conditions desired, (*a*) a pearlite anneal, (*b*) a quenched and tempered structure or (*c*) a hardened structure.

Thus, in graded annealing to pearlite it is proposed to cool rapidly into the intermediate zone and then reheat to and hold in the pearlite zone. In graded quenching and tempering the required tensile properties can be obtained without entering the martensite zone with all its danger of internal cracks, for the complete transformation takes place where the steel is hot enough to yield plastically to the associated volume changes. "Interrupted hardening" gives a uniform hardness throughout the piece, and can be utilized by users of low alloy steels for machines and for engineering purposes. Straight carbon tool steels do not respond to this method of hardening if file hardness is required, but satisfactory results have been obtained with high speed steel.

Daasch discussed the mechanical properties on three steels treated by the orthodox method of quenching and by what he terms "hot quenching" methods — that is, by plunging the heated steel directly into a quenching bath at drawing temperatures. The steels studied included a plain carbon, a nickel-chromium, and a carbon tool steel. For equal tensile strengths, the hardness and ductility values of ½-in. bars are slightly lower after hot quenching than after an oil quench and draw; similar tensile properties may be obtained by either method. The point is made, however, that hot quenching should prove more economical than the double treatment of quenching and reheating.

Davenport, Roff, and Bain discuss the effects and elimination of microscopic cracks in hardened steel in an important paper in April *Transactions*. Their studies are the outgrowth of the previously mentioned work on the rates of transformation of austenite, and their results depend on the use of the "hot quenching" method (to use Daasch's terminology) at temperatures above the martensitic transformation. The steel is permitted to remain in the quenching bath long enough for all the austenite to transform, and such products of direct austenite transformation in the zone above about 500° F. are free from minute cracks. Many carbon steels, after the conventional quench, exhibit intragranular cracks across the needles of the martensite — as discovered by F. F. Lucas some years ago. These are not obliterated by tempering, and are reasonably associated with the low impact values to be expected in drastically quenched steels.

The facts brought out in these papers give a rational explanation of the difference in quality between wire made by the "new process" and by the "old process" of patenting, different only in that the rod is quenched in molten lead in the one and air cooled in the other.

Reference should also be made to the low

internal stress heat treatment discussed by C. W. Briggs before the Buffalo Convention. Aging tests on cast steels previously quenched just below the critical point show a large increase in yield point, tensile, and hardness without much loss of ductility.

Cleaning and Rust Preventing

The subject of descaling of forgings has received much attention. Conventional methods of scale removal have relied upon variations of two main ideas — abrasion by tumbling or blast cleaning, and solution by pickling and electrolysis. Improvements in equipment have been such that it can be introduced into the production line without danger of creating a dust or fume nuisance.

Small forgings which are handled may be tumbled in a barrel containing hardened stainless steel stars; when rotation is reversed, the work is automatically discharged and the stars separated and returned to the cone surrounding the screen. Such a barrel may be used either for dry tumbling, or with sand and water for removing the scale, or may be modified to tumble the pieces in dilute sulphuric acid. Two or three different systems of electrolytic cleaning have also been promoted.

For scale removal from any size or shape of heat treated parts many prefer blast cleaning with steel abrasive. The operation is fast and, in properly designed equipment, dustless, so it can be located in any production line. Blasting time can be quickly altered to handle hard or soft, tight or loose scale. Since all scale is removed, the metal takes a dull silver finish which shows up any checks or cracks, good for inspection, and free from any deposit that would retard cutting speed or destroy tool edges.

Numerous liquid removers for removing machine oil from parts before plating or assembly are now available; most interesting of these are the volatile, non-flammable solvents.

Finally, attention should be directed to developments in materials used to preserve the surface condition of metal when placed in service. To the conventional slushing compounds have been added liquids which may be applied by brushing, spraying, or dipping, and which will dry to an elastic and lustrous finish. It is claimed that these new coverings possess several times the resistance to corrosive elements which is given by ordinary ready-mixed paints or so-called acid resisting paints.

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SAVINGS

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	30	.008	.012
	60	.014	.022
1	30	.018	.025-.032
2	00	.022	
2	30	.026	

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TYPE OF CASE: At 1600°F to 1650°F the case produced is 1.00 carbon with 0.18-0.20 Nitrogen. At 1550°F carbon .90 with Nitrogen 0.25. Result: Pieces treated in Holden Hard Case have harder wearing surface, plus no embrittlement of the core. It gives you a piece that will stand greater impact without breaking.

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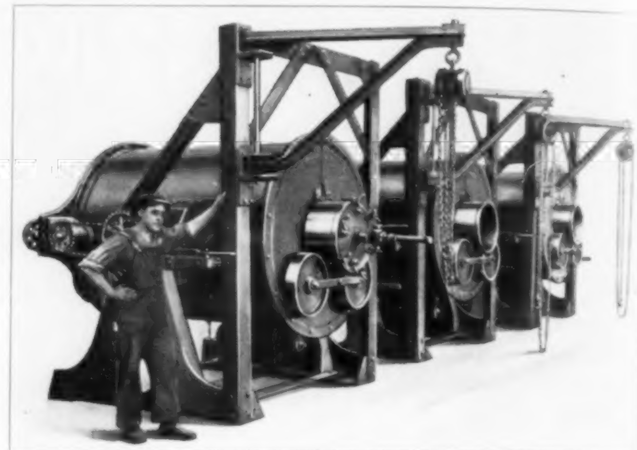

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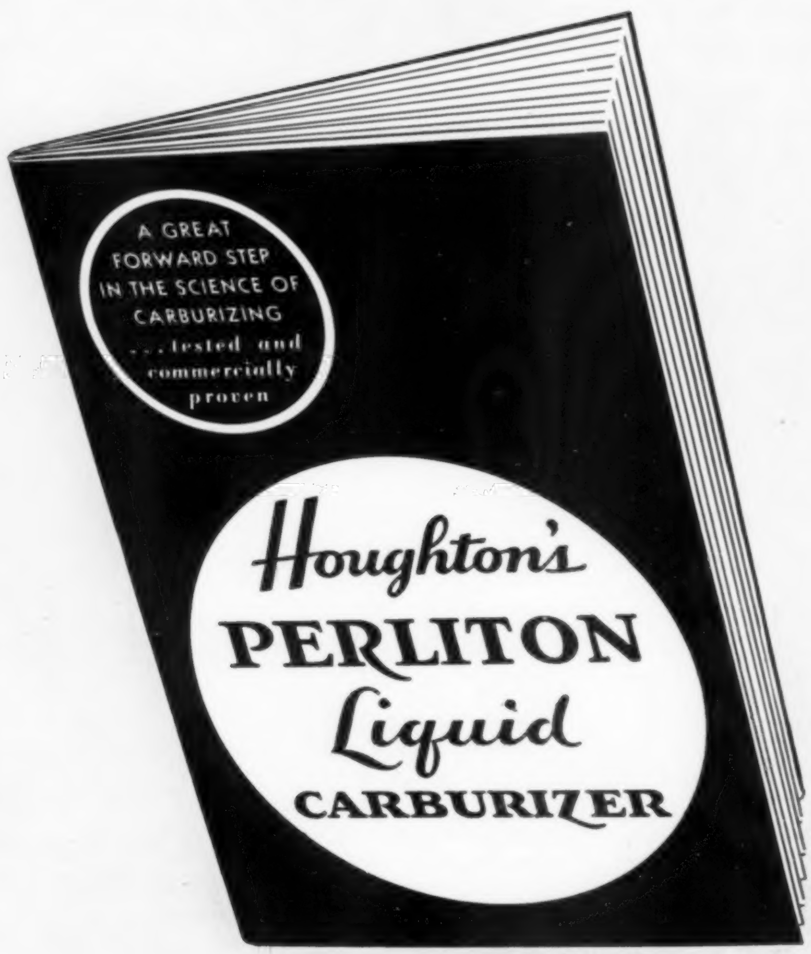

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TESTING and CONTROL INSTRUMENTS

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TEMPERATURE MEASURING AND CONTROL EQUIPMENT

WHEN one considers the art of heating materials in process, it is immediately apparent that the present status is based on equipment for the accurate measurement and control of temperature. Of course, "control" also involves efficient fuel burners or electric resistors, and adequate furnace or oven design; with these a good job can be done manually — that is, good as judged by standards of the last generation. But the demands today are for accurate and uniform heat treating operations, regulated with a precision which requires sensitive and rapid-acting automatic equipment, all but human in its reactions to changing conditions in the ovens, tanks, and furnaces.

It results, therefore, that progress has been steadily toward more accurate and more rugged temperature measurers, and toward more sensitive and quicker acting equipment for controlling the temperature and preventing it from fluctuating from a previously set program. In a word — better pyrometers, more accurate recorders, and almost-human control devices.

Thermometers and Pyrometers

No changes in the principles underlying pyrometry have taken place in a long time — they were well known to physicists in the last century. In the application of these principles, however, mechanisms have been devised and refined in design as there has come about a better understanding of the capabilities of each measuring method.

For instance, the mercury or alcohol thermometer, while excellent for an indicating device at the spot, became a practicable instrument to drive a recorder with the development of stainless steel bulbs and capillary, and special steel helices, capable of resisting the high bursting pressures thrown into a closed system by the expanding liquid. They are now giving good service up to 1100° F. Temperatures up to 800° F. are satisfactorily recorded by a gas thermometer, in itself a device known for a long, long time. In this, a metallic bulb of considerable volume is filled with nitrogen, say, and a capillary tube leads to a helical coil made of thin-walled rectangular tubing. Any gain in heat at the bulb increases the pressure in such a closed system, and causes the helical coil to unwind proportionally. This moves an attached pointer with so much force that recording pens and electrical contactors may be moved without great impairment of accuracy. Such equipment can be made more sensitive in a narrow range of expected operation (as, for instance, in lacquering and drying ovens) by partly filling the bulb with some liquid which boils at temperatures just below the operating range. Pressure of vapor rising from this liquid increases sharply with temperature and therefore produces large movements of the indicating needle with small fluctuations at the hot bulb.

Recent improvements in such devices have to do with (*a*) the manufacture of the immersion bulb of one of a wide variety of modern alloys or plated metals, properly chosen, (*b*) with use of bi-metals in the recorder to compensate for changes in temperature at that point, and

(*c*) with the use of modern welding and brazing methods for a permanently tight pressure system.

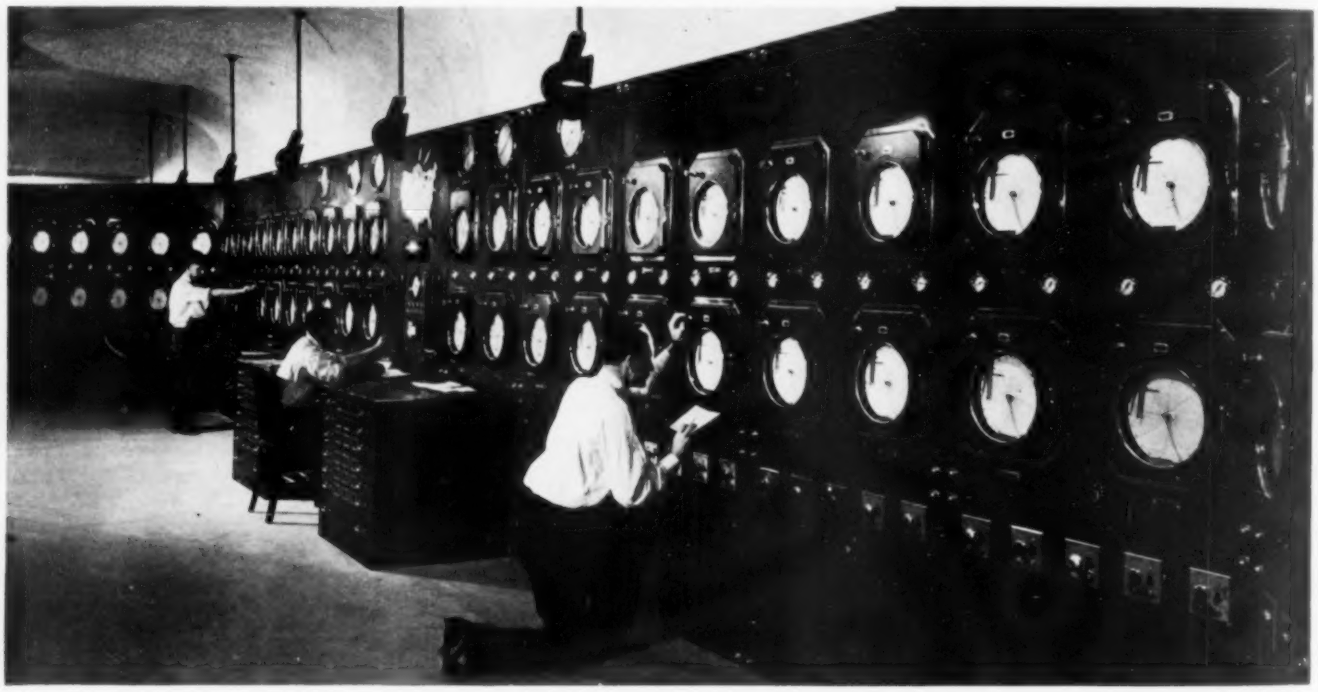
From temperatures somewhere within this moderate range up to about 2200° F. the base metal thermocouples are well adapted and almost universally used. (Rare metals are good up to 3000° F.)

Accuracy, permanency, and interchangeability are the prime requirements for thermocouple wires. This in turn demands the highest degree of metallurgical perfection. Even after all has been done in the way of chemical and mechanical control, each spool of wire must be tested against a standard as to electromotive force. Then, too, a couple may *reproduce* its readings very well, but the e.m.f. generated may not bear the same relation to a standard as another couple; hence the absolute readings of electromotive force must also be within control. For this reason matched coils are usually classified by the manufacturer as to actual e.m.f. at a certain reference temperature, and the purchaser bears this in mind when re-ordering, else the calibration of his indicating instruments will be correspondingly in error.

As in all operations under close technical control, the bulk of the thermocouple wire manufactured falls in a median range. But some is high in absolute e.m.f., and some is low. A sensible proposal is to use this minor production for extension leads from the "cold" junction to the instrument panel. Such a plan would not increase the installation cost unduly, would remove occasional difficulties due to an unwitting substitution of high e.m.f. couples for median e.m.f. couples, and avoid counter e.m.f.'s at "cold" junctions which frequently are quite hot, and sometimes not equally hot.

Continual study by manufacturers of thermocouple wire has resulted in a corresponding improvement in the accuracy as to electromotive force. A German firm believes that melting under vacuum is a prime factor in high quality; American practice is to melt in high frequency furnaces under a suitable flux. Tests on the German wire have so far failed to indicate any superiority.

Permanency of thermocouple elements involves the matter of protection. Yet sometimes the very bulk of an adequate protecting tube defeats the purpose, for it causes too great a lag in the recorded temperature. A case in point is the measuring of ladles of alloy just before casting. Fortunately the usual elements are fairly insoluble in many molten metals, and the



No Less Than 64 Recording Regulators Are Installed on This Panel Board to Keep Temperature and Humidity Correct in the Air-Conditioned NBC Section of Radio City, New York

junction can be thrust bare into the melt. In more corrosive alloys the wires may be protected by a metal tube or by a refractory tip perforated with two holes through which the wires are fed as they are consumed, relying upon the conductivity of the molten metal to form the hot junction. This matter was discussed by R. D. Bean in METAL PROGRESS in October, 1931.

(Another plan of removing the errors due to protecting tubes was described in July by E. O. Mattocks. His plan is adaptable to non-corrosive gas atmospheres, which are sucked through a hole at the very end of the tube past the hot junction.)

Difficulties with immersion thermocouples and their protecting tubes obviously increase with the temperature, and steel-making operations have therefore been forced to rely upon optical or radiation pyrometers. One recent suggestion by Dr. Fitterer of the Bureau of Mines has attracted much attention. His thermocouple is non-metallic, consisting of a hollow graphite tube with a silicon carbide rod down its center; it is refractory to the highest degree and the thermal e.m.f. is some 30 times that of platinum couples.

Surface temperatures on steel in the heat treating range are difficult to measure correctly, as everyone who has tried it knows. One device (albeit not optical) has been used successfully for heat treating rail ends in track. It is merely a thermocouple with rugged elements set parallel and sharpened to a point. These points are thrust against the surface, breaking through any scale, and the hot metal forms the junction. (See METAL PROGRESS, April, 1931.)

Another interesting device for taking the surface temperature of a roll in operation uses a thermocouple made of flat wire, butt welded, and stretched like a bowstring in a swiveling handle so the junction can be pressed against the roll while it is turning. Thermal e.m.f. generated at the contact is carried by wires back to an appropriate indicator.

Optical and Radiation Pyrometers

The optical pyrometer was perfected at least 20 years ago to a point where the equipment involves far less error than the uncertainties connected with the hot body itself and its surroundings (such as smoke, flame, and incandescent brickwork). Hence there is little to report on this matter other than to call attention to an ingenious use of spectral lines to measure the temperature of flames. Some dry salt is fed into the fuel supply and the sodium line in the spectrum is then matched against radiation of the same wave length emitted from a calibrated incandescent light bulb.

"Action at a distance" is desirable also when the hot object is moving, as a billet entering a rolling mill. Operating temperatures for aluminum and magnesium are also below visible heat; for such purposes radiation pyrometers have been successfully adapted. When maintained with intelligent care, these devices (which focus heat on a thermopile, or a series of thermoelements) are quite accurate and the current generated is sufficient to operate an indicating instrument, but hardly enough for controllers.

The tardy application of vacuum tubes as power magnifiers was commented on editorially in METAL PROGRESS no longer ago than October in 1931. At that time the leading instrument makers felt that such applications would be confined (at least until vacuum tubes of the accuracy and stability required in pyrometry became available) to systems acting as an optical and electrical magnifier of some delicate mechanical movement, or to non-proportioning devices requiring *instant* response.

Photoelectric cells have been used as "electric eyes" to interrupt a heating current when a rapidly rising temperature reaches a set limit. An instance was described in the January, 1932, issue, where valve stem ends, individually heated by current flowing between gripping dies, were released to fall into a quenching tank when the proper temperature was reached.

A more recent application of the principles commented on in the above-mentioned editorial is the development of a photoelectric pyrometer for measurement of incandescent bodies (1500° F. and up) and an electrical recorder for a radiation pyrometer, useful for ranges from 1000° F. up. The former consists of a photoelectric tube in a suitable housing which receives the radiation and transmits a proportional current to amplifying tubes in a panel mounting. Such equipment can control devices by adding thyatron tubes. In the second-mentioned equipment the mechanical balancing of the current from the radiation thermopile is replaced by an optical system based on a mirror on the galvanometer needle, a beam of light, and photoelectric and pliotron tubes which magnify the currents so they can operate high-torque motor elements.

Another interesting device is one for closing fuel valves the instant the flame drops (thus guarding against explosions of unburned gas).

It depends upon the fact that a flame is a slightly ionized gas mixture, and will conduct a small current, whereas hot air is not ionized by heat radiated from incandescent brickwork. A rod of high temperature alloy is therefore thrust into the base of the flame; current is carried by the flame to ground (some part of the setting or burner with which it is in actual contact). A grid glow tube magnifies this small current into one large enough to close a relay controlling the fuel supply valve. If the flame drops, the current stops, relay opens, and the fuel valve closes.

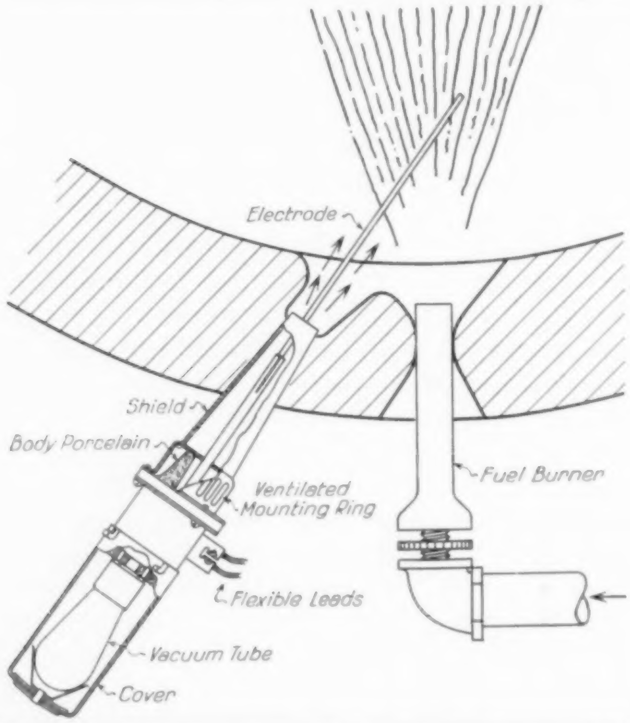
Recording Equipment

A small electric voltage, or the current induced by it, is the thing which must be measured and indicated by the recorder. Obviously, either the current itself may be measured by an appropriate ammeter, or the e.m.f. generated may be measured by a voltmeter or a potentiometer. While both methods have been vigorously promoted, and careful purchasers will always select the type of equipment best suited for the particular problem or process in hand, the trend has been toward the potentiometer type.

It is perhaps superfluous to write that the ammeter is a simpler device, requiring principally a moving coil and attached pointer. The currents generated by the thermocouple are so small, however, that little or no extra work can be done by the coil, even for dragging a pen over recording paper. Auxiliary devices increase the complexity of the recorder toward that of the potentiometer recorder (which, as everyone knows, automatically balances the e.m.f. of the couple against another e.m.f. originating in a standardized source within the instrument).

In the potentiometer system the trend of numberless improvements in detail has been toward more ruggedness and more accuracy. Registrations or control movements are made frequently — on the order of 20 a minute — contacting points are subject to corresponding wear, and clearances, even though small, wear larger. Efforts are continually being made, therefore, to eliminate these sources of error, to modify the electrical design so that a small change in e.m.f. at the hot junction will make a large change in the indicating system, and to improve the control mechanism so it will follow these changes more and more closely, not so much by steps of uniform size, as by intervals accurately following the movement of the indicator.

In all these changes the makers have sought primarily to insure more certain reproducibility of registration corresponding to a given change in temperature being measured. A byproduct of this effort has been a continually increased sensitivity up to 0.2% at maximum range, considerably beyond that of the best base metal thermocouples in that respect.



Small Current Passing Through Ionized Gas in Flame Is Magnified by Vacuum Tube to Control Shut Off, Should Flame Drop for Any Reason

Controlling Equipment

The above has had to do primarily with improvements in the indicating and recording system. In turn this has been matched by an improvement in automatic devices for controlling the temperature at the point measured. (Of course, what is said applies with equal force to many other matters under accurate control, such as pressure in a hydraulic system, or CO_2 in furnace gases.) Frequently one finds the control system quite divorced from the measuring system except for a few electrical wires or a simple mechanical linkage.

The simplest control is the "on-and-off" type. Take one of its most difficult applications — a fuel-fired pot for cyanide hardening. The setting, pot, and liquid contents have a large capacity of heat as compared with the fixture of tools

which may be immersed in it, and changes in temperature are somewhat sluggish. When the indicator arm swings a set distance below the desired temperature, a contact is closed and the fuel valve opens. As soon as the inrush of heat brings the temperature back to a set distance above the desired temperature, the first contact opens and the other closes, and the fuel is shut off. Actual temperature at the thermocouple then swings leisurely down and up within the zone of control.

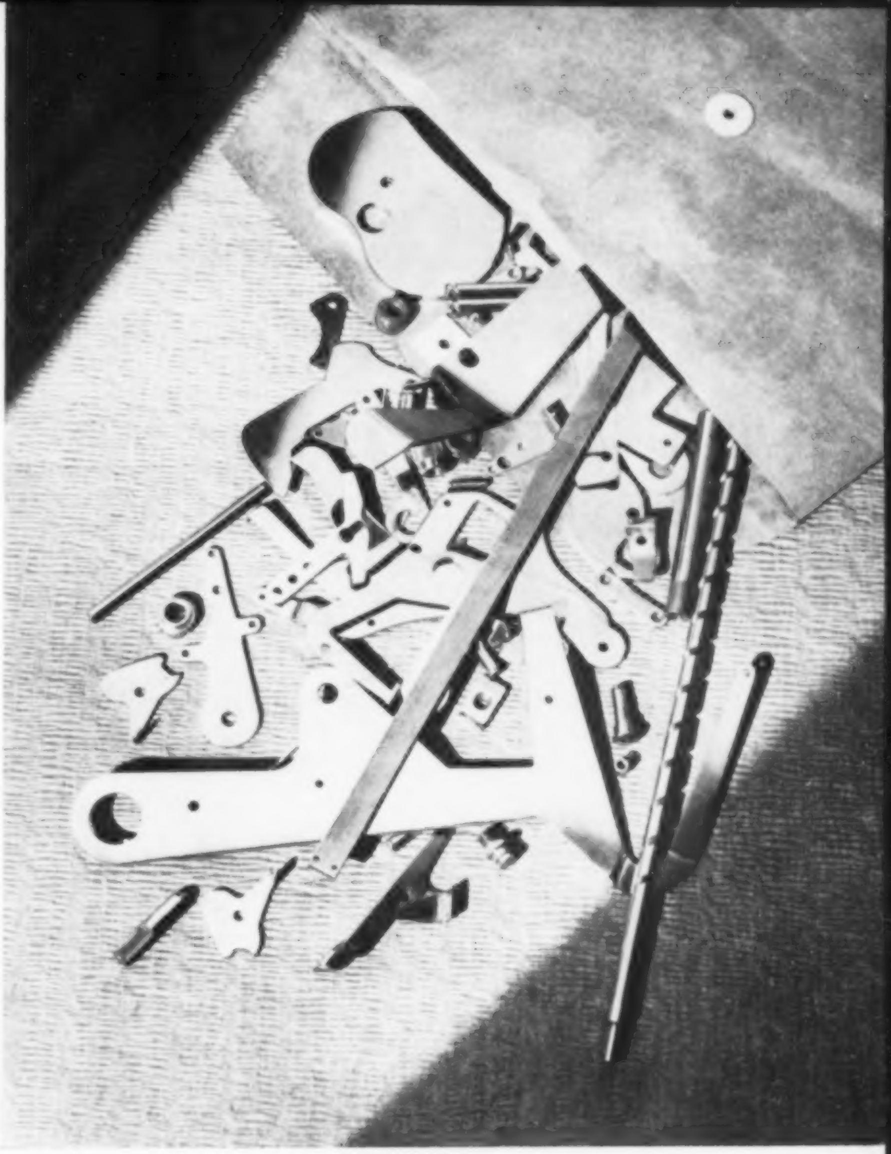
There are several ways by which the on-and-off control can be made more sensitive. One is by magnifying the swing of the pyrometer pointer, and setting the control points closer together, but there is a distinct limit to this type of refinement. One way of magnifying the swing is to build two supplementary thermocouples into the control instrument, one to get a little current as soon as the galvanometer needle swings below the desired temperature. This generates an e.m.f. acting in the same direction as that coming from the thermocouple in the furnace and swings the needle far enough over to open the fuel supply. This is done, not by the thermocouple in the furnace but by the combined action of thermocouples in the furnace and in the instrument, and the new influx of heat rapidly brings the furnace back up to the upper control point and the fuel valve is closed. In this manner a slight over-run of the pointer will be quickly counteracted.

A third modification is the use of an interruptor — the "on" position would be reversed automatically to "off" after a second or two, and remain so until the next impulse is received from the indicator. If the temperature is still too low, the control would go "on" again for another brief interval.

While the on-and-off system with some such refinement as noted above is usually sufficient for installations which do not change very rapidly, the trend in modern production is to use continuous furnaces built with insulating firebrick — that is, to store as little heat as possible in the furnace itself. Temperature variations in such a system develop rapidly; the control must operate rapidly, and counteracting operations, acting rapidly, must not overshoot and cause wide swings in temperature, or "hunting."

This undesirable situation may often be avoided by control of "on, neutral, and off." It might be likened to an electrically heated furnace with two circuits; the main circuit carrying 100 amp. would be somewhat too little to counterbalance radiation losses and out-take by heated work. An auxiliary circuit carrying 10 amp. could then be switched on, automatically, when the indicated temperature fell below the required temperature by, say, 10°, to be switched off again when the temperature had risen to, say, 10° above normal. Obviously this range could be adjusted by contacts which would be closed by the shifting pyrometer needle. In this case the "neutral" position corresponds to the main circuit, and its success depends on the condition that the main circuit would never furnish enough energy so the temperature in the furnace would continue to rise, even with the auxiliary current off.

A better illustration of the on-neutral-off system would be a control for gas burners, where "neutral" represents a hand-set opening of the gas valves which is about right for the furnace and its load. If the temperature rises the valves close a definite amount; if the temperature lowers the valves open a corresponding amount. The amount of change in fuel supply is, of course, a



Some of the Stainless Steel Parts Going Into a Modern Temperature Recorder and Controller

function of the way the valve ports are designed, and this becomes a vital factor in the success of such a control. It is clear that when the temperature falls, it is necessary to over-compensate in order to bring it back to the desired level, and this over-compensation may cause some violent swings in temperature, or "hunting."

It is evident that efforts to improve the accuracy of control usually involve some means of reducing the heating rate as the control point is approached from below (and vice versa), else the temperature will overshoot by a degree depending on the relative thermal capacity of charge and atmosphere to that of the refractories, and also by the lag caused by thermocouple protection tubes and muffles. An important recent development for electric furnaces, therefore, consists of a simple auxiliary instrument for cutting this rate of heating from the maximum to any desired fraction as required, without recourse to expensive transformers and voltage taps. It utilizes a mercury switch, opened and closed by a rotating cam; the adjustment for varying the heating rate moves the switch from one end of the cam to the other, which changes the percentage of time "on" and "off."

"Three position control" has been extensively used in the place of "on-neutral-off." In it, three distinct electric circuits lead from pyrometer to valve or heating circuit. One is completed when temperature is high, and puts in the minimum fuel supply. Another is completed when temperature is low, and turns on maximum fuel supply. The third is completed when temperature is at control point, and sets the valves midway.

Multi-Point Control

If the on-neutral-off control gives a smoother regulation than the on-and-off control, a multi-point control should be better yet. By this is meant any type of mechanism, either hydraulic, pneumatic, or electric, which is capable of moving the fuel valve in very small increments and holding it at any point between fully open or fully closed. Such a valve then becomes in reality an adjustable orifice.

In one electrically driven system, this is effected by two motors, one of which moves the neutral position on the valve either open or shut a small but definite step for each time the pyrometer indicating arm is below or above the control setting. These corrections in neutral position therefore follow the trend in the temperature. A second motor, operating with the first through a Stephenson link, is working simultaneously in such a way as to hold the temperature on the control setting.

This is equivalent to an automatic shift of the "neutral" position (equivalent to the main supply of fuel for approximately uniform operation) up or down, depending upon whether the furnace is losing or gaining heat, respectively.

Still another electrical system which operates from a potentiometer recorder utilizes the electrical current flowing through one or the other leg of a Wheatstone bridge to close a circuit to the corresponding right hand or left hand rotor on a single motor shaft. This motor moves the valve stem up or down and the shaft is also geared to the central arm of a balancing potentiometer placed in the circuit in opposition to the potentiometer in the recorder. As soon as these two potentiometers balance, the circuit to the motor is broken, and no motion starts until the temperature of the thermocouple again changes. Thus a swing in temperature in the furnace resets the valve by an amount proportionate to the deflection of the primary controlling device.

Finally, a successful method of avoiding hunting is to move the throttling range (that is, the actual temperature for "on" and "off") as the temperature at the thermocouple moves away from the desired point. This is done in a pneumatically controlled system by altering the position of a flapper valve governing the pressure on the air line which operates the main fuel valves, and this in turn readjusts the position of the main valve so as to keep the temperature constantly at the desired point.

The electrical devices necessary to effect these movements may be quite intricate, and are beyond the scope of this article. The telechron clock, which operates on rather small currents, has been applied extensively, especially to actuate mercury switches on lines carrying much larger currents for motor-operated valves and even heating circuits. Several manufacturers use compressed air for actuating the fuel and air valves; a swinging wedge-shaped vane cuts off a greater or lesser amount of exhaust, and thus builds up a variable back pressure which is directly translated into valve-stem positions by action against a spring-supported diaphragm affixed to the stem.

It is also clear that the fuel and air valves should be properly engineered for the type of control, valves which are balanced against internal pressures, which *(Continued on page 128)*

OPTICAL & MECHANICAL

TESTING INSTRUMENTS

MICROSCOPES deserve first mention in any review of testing instruments, since Dr. Sorby's first metallographic examination marked the beginning of physical metallurgy — that branch of the art in which consumers of metal are primarily interested. One can do no better than quote what the late W. L. Patterson wrote for METAL PROGRESS in November, 1930, on a decade's advances in metallographic microscopes:

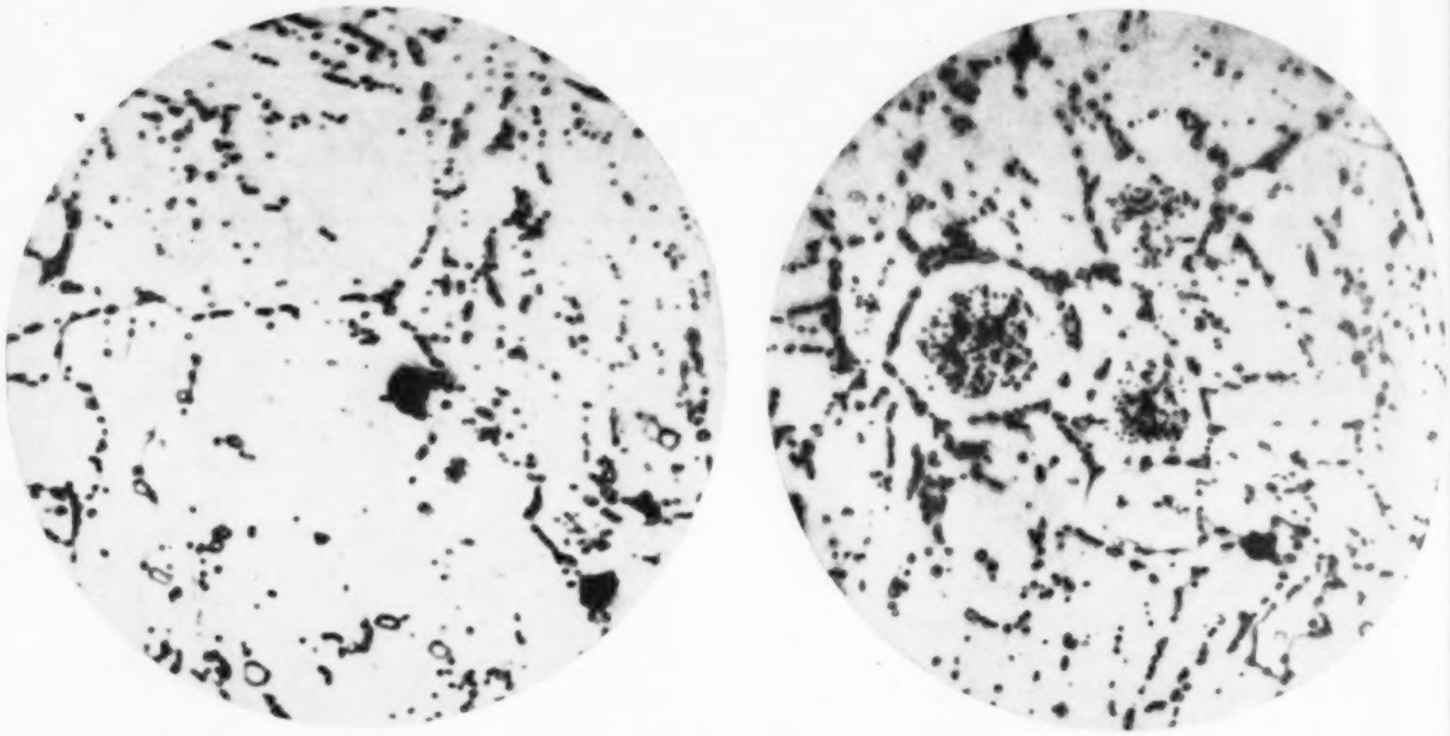
"While the trend of the years has been toward the Le Chatelier type of instrument, it is very evident that the original models (with stage support on one side, long unsupported tubes, condensers and illuminants with all kinds of adjustments) would certainly not be adequate for present-day requirements, when the metallographer is not required to become a trained optician but must have an instrument which is immediately available for use, without tedious adjustment.

"With the demand for higher magnifications the microscope itself required revision. The base and column needed to be heavier and to be locked rigidly to the bed so as to become in reality one piece with the camera. The stage and its support, formerly either one-sided or an assembly of many pieces, needed a more rigid construction and less chance of springing or loosening.

"The fine adjustment, which formerly moved the entire stage and specimen, was the greatest cause of trouble because the weight of these parts was too much for the delicate motion required. For this reason, the present-day instruments carry only the small weight of the objective on this screw thread. The result is that in addition to being able to obtain an extremely sharp focus upon the ground glass, the instrument will not sag out of focus over a long period of time.

"Another great time-saver available to the present-day metallographer is the permanent adjustment of vertical illuminator and condensers, and the fixed relation of the parts to each other, thus enabling the operator to give all of his time to the study of the metal under consideration."

These principles were carried to their logical conclusion in the very fine equipment built for the Cadillac laboratory, and described in METAL PROGRESS in August, 1932. This instrument was designed for *production*, and all details were arranged to relieve the operator of muscular and ocular strain. These matters include binocular microscope (and head rest) for general survey of the surface, vertical objective with filar micrometer which can be put into action by simple movement of a lever, wrist rests for stage and focusing controls, a small electric light for illuminating verniers, rotating stage plate for holding specimens "straight up" during examination,



New Objectives Reveal Particles About 200 to 300 Atom Diameters. Both magnified 4000 diameters; identical specimen of chromium-iron alloy (low carbon) oil quenched from 1750° F., then heated for 1 hr. at 1450° F., and air cooled. Left taken with 1.40 NA apochromatic objective, right with 1.60 NA mono-chlor-naphthalene objective. (F. F. Lucas)

and a "Point-O-Lite" incandescent bulb for light source. Whereas two or three hours at most was the longest time a metallographer could work uninterruptedly at old equipment, with the new a normal day's work could be done without undue fatigue.

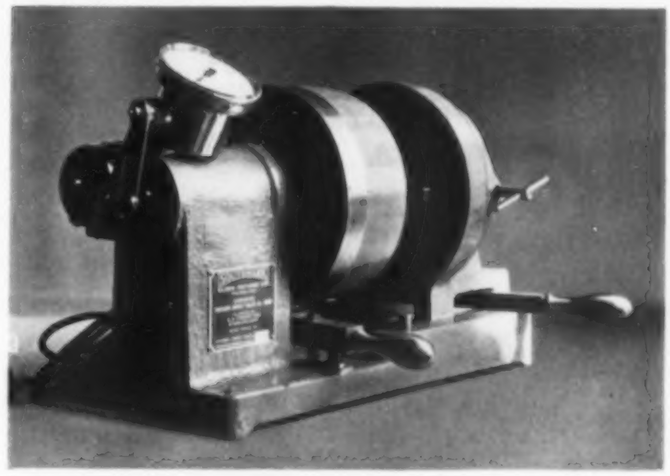
The matter of illumination has been given much attention, not only because an unsteady light source is a nuisance, but also because a correct lighting system has so intimate a relationship with the performance of the machine as a microscope. W. Zieler, in an interesting article in Metal Progress in January 1933, describes a method (which he calls "darkfield illumination") adapted from bacteriological work. Instead of using a prism or plane glass reflector in the microscope tube, an annular mirror is used which directs a cylinder of rays surrounding the axis of the microscope and outside its lens system. These rays enter a massive spherical lens which directs them against the object at a high angle, as is necessary to get there beneath the lens on the objective. None of this light is reflected up through the microscope from a truly plane surface — only that light which glances from the surface relief. The result is that such irregularities as the finest carbide particles stand out as intense points of light against a black ground, irrespective of their color. Since the microscope lenses are used only for magnifying (and not for the combined job of magnifying the image and condensing the illuminating rays), a certain amount of haziness due to internal reflections, which has a disturbing influence upon the contrast of the image obtained with vertical illumination, is eliminated.

Another interesting possibility in increasing the usefulness of metallography other than by mere magnification is by the use of reflected *polarized* light. A system especially designed for opaque specimens is now available, and should be valuable, especially in the study of nonmetallic inclusions.

Francis F. Lucas, the eminent metallographer and microscopist with Bell Telephone Laboratories, has also contributed to the advancement of

the art by the design of a new precision microscope. It includes no new fundamental principles, but rather uses the available optics most efficiently. Higher magnifications have been the style for some years — frequently, however, these have been made by bellows extension on the camera end, and show little if anything that an intent study of a lower power view would not reveal. Better resolution of the fine structure has now been achieved by use of shorter wave lengths, properly selected according to the color of the details searched for, by the use of objectives of high numerical aperture corrected for dominant wave lengths in the selected light, by the proper preparation and etching of the specimen, and by a rigid unit capable of photographic exposures up to 30 min. without vibration or creep in the adjustments.

This equipment was described in a paper before the Detroit Convention, American Society for Metals, in 1933. It includes an objective of 1.60 numerical aperture for use with mono-chlornaphthalene as an immersion fluid. Its capabilities — in comparison with the best that could be done at the same magnification (4000×) with an apochromatic objective of 1.40 numerical aperture — are shown in the accompanying views of a specimen of 13% chromium-iron forwarded by Dr. Lucas, and first published in *Journal* of the Franklin Institute, June 1934. Heat treatment was such that a secondary constituent has been precipitated and accumulated into isolated particles of 200 to 300 atom diameters.



Torsional Impact Machine for Hard Steel, Wherein a Round Specimen Is Suddenly Twisted to Failure by Engaging a Rapidly Rotating Flywheel

Estimating Chemical Analysis by the Intensity of Prominent Lines on a Spectrograph

One cannot exactly specify by what percentage the 1.60 N.A. objective increases the resolution. It has produced for the first time in the history of science a crisp brilliant image of extremely small particles. If the specimen is photographed on the same equipment except with an apochromatic objective of N.A. 1.40, the particles are only seen as hazy detail; groups or strings of them appear continuous, not like a chain of pearl beads where each bead may be clearly seen sharply differentiated from its neighbors.

Spectrographs

Production of metal of excessive purity furnished the first use for the spectroscope in the metallurgical laboratory. In no other way could the impurities in, for instance, 99.99% pure zinc (now an article of commerce) be identified with exactness. Furthermore, there are interesting possibilities in the use of a spectrum for the quantitative analysis of less pure metals, alloys, and alloy steels. F. E. Roach summarized the situation as to steels in this magazine in June, 1933, and outlined methods where chromium, manganese, silicon, titanium, nickel, vanadium, tin, and copper may be determined from one

spectrogram in amounts up to 2% each. Time required is much less than would be necessary for a chemical analysis to determine even a single element.

Portable spectrographs with quartz prisms are now available which register certain portions of the spectrum; short wave lengths are suitable for analyzing non-ferrous metals. Thus, tin, lead, cadmium, and magnesium in zinc-base die castings are easily estimated. Where the spectrum of the element under study is close packed and complex, other spectrographs are available with higher resolving power, and which require more than one photographic plate to span the entire spectrum. Optical comparators are necessary in this work, such as the one illustrated, wherein the intensity of a given line is measured by a photo-electric cell and the results read directly from a scale just below the inclined screen.

Radiography

Radiography has received an impetus from the requirement that important welded equipment (such as boilers and penstocks) must be proven to be free from internal defects by radiographing the seams from end to end. While this is usually done with X-ray equipment, R. F. Mehl and others have used rays from radium for thicknesses of metal beyond the capability of X-rays to penetrate. If a supply of the metal or its emanation is available over night on rental or loan, numerous smaller objects may be mounted at suitable distances in all directions from the capsule and exposed simultaneously.

Electrical progress has been reflected in the form of X-ray tubes of long life and higher voltage (even up to 300,000 volts). These higher voltages have emphasized the need of safety devices; the tube is usually sealed in oil and operated at some distance from the high tension transformer and rectifier. This is the design installed at the Washington Navy Yard; the tube operates at 10 milliamperes and 220,000 volts.

In shock-proof portable apparatus, capable of penetrating 4 in. of steel, such as that used for inspecting welded seams in the Boulder Dam penstocks, a 300,000-volt tube is immersed in oil in the same grounded tank which houses the high voltage generating equipment, kenotron rectifiers and condensers. It is believed that this equipment, designed for practically continuous operation, generates X-ray energy in the largest amounts hitherto attained.

While a 900,000-volt tube was constructed for experimental purposes in a New York hospital, a 200,000-volt tube was the highest rating commercially available as late as 1931 — a fact which indicates the progress in this branch of science.

X-rays are being used to an increasing extent for the study of the atomic arrangement of metals. The highly specialized interpretation of diffraction spectra has thrown much light on many theoretical problems, such as the nature of various solid solutions, and now is being utilized to study and control the structure of wire and sheet, where directional properties or "fiber" are important.

An interesting footnote may be added to the effect that surface films, only a few atoms thick, may be analyzed in a similar manner by diffraction of medium-speed electrons emitted from the cathode of a special X-ray tube.

Hardness testers are probably the most useful routine testing equipment in the metallurgist's kit. Present equipment for the accurate measurement of the diameter or depth of impression, or the load on the penetrator, are a long way from the methods in use only a few short years ago, when a thing was either "file hard" or not so hard. Old-time members of the American Society for Metals can remember the lengthy sessions devoted to hardness testing — a subject then as engrossing as grain size is today!

Recent progress has been principally toward a recognition of the capabilities and limitations of each of several systems of measuring hardness and their interrelation (for there is as yet no "universal" method). A notable instance is the investigation by American Brass Co. and Bell Telephone Laboratories on the relation of the Rockwell hardness test and the tensile strength of high brass sheets, cold rolled various amounts. Accurate relationships were discovered so that the method was incorporated in a specification and is most useful in the mill for controlling heat treatment.

One problem which has existed since the discovery of good hardness machines has been the testing of very thin metal. A recent solution has been offered in a "superficial hardness tester," which utilizes smaller loads on the penetrator and a more sensitive depth measuring system. This meets a demand for testing razor blade steel about 0.006 in. thick, by resting a single strip on the anvil instead of the acknowledged inaccurate method hitherto in vogue of testing a pile of them. Such equipment is also useful for testing thin carburized and nitrided cases which are

broken through and fractured by machines testing for indentation hardness.

Physical Testing Machines

The variety of physical testing machines is so great that it would take volumes to discuss the subject adequately. A trip through the research and control laboratories of a representative manufacturing concern like the Hoover Vacuum Cleaner Co. indicates that for every "standard" machine there exists a room full of special equipment designed for life tests of this, that, or the other part, or the entire sweeper, in conditions closely simulating service.

Special purpose testing machines seem all the style, therefore. Thus — test coupons cut from the walls of welded pipe needed to be pulled on the spot to convince the operators that the results were bona fide, so a portable tensile machine including a hydraulic pump and pressure gage is now on the market not as large as an oxygen cylinder!

From the great mass of material available on new testing equipment, one may select for brief description the torsional impact machine because it gives information on the toughness of hardened steels, and thus carries on where the Izod and Charpy tests leave off. A view is shown on page 125. It was devised by Messrs. Luerssen and Greene of Carpenter Steel Co. to test the tough-hardness of various tool and die steels. The left flywheel is brought to measured speed by a friction drive from the small motor at the rear, and at the proper moment a sleeve in the housing at the right is moved forward. This sleeve carries the test piece; the latter has a cross-arm on its forward end and this strikes a pair of pins on the spinning flywheel and the specimen breaks almost instantly. Work required is measured by the loss in speed of the flywheel. A test takes about a minute.

This test has proven useful in determining the best heat treatments for high carbon steels, and is being applied to various cast irons, case hardened steels, and in fact should be a useful test on all material which cannot satisfactorily be tested in the form of notched bars because of minute variations in the shape of the notch.

Dilatometry is a study which is attracting increasing attention. Three models of equipment are now available, one of which transmits the expansion by optical methods through the reflection of a light ray; the others use a mechanical lever system.

PYROMETERS

(Continued from p. 122) do not develop much friction at the stem, and whose ports are so designed that proportionate flow results from proportionate settings. Several valves now on the market meet these requirements.

Program Control

The above remarks as to the recent developments of control apply to the regulation of temperature about a fixed point. Usually it has been assumed that the furnace should be heated up from cold (or recover heat after the introduction of a cold charge) in the least possible time. A better analysis of many problems indicates that the *rate* of heating of a cold piece has a great deal to do with quality of the product.

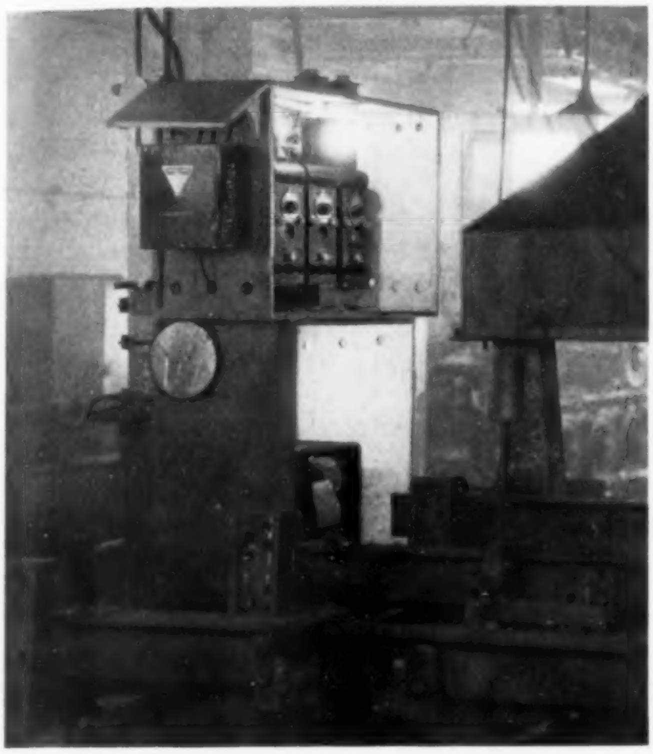
This has always been considered in the heating of heavy masses of metal, where internal rupture will be the reward of too much haste. Rate of heating also influences warpage of the heat treated object. Furthermore, many problems of "hunting," in the control of electric furnaces, are solved by reducing the heating rate, or speed at which a given deficiency in temperature is recovered.

"Program control" is another device for the same end, where the temperature is designedly varied over wide limits according to a definite time schedule. A simple example is a cold furnace which starts to heat automatically at 4 a.m. so as to be at operating temperature 3 hr. later when the workmen arrive.

A more complex example is a batch of gears which are introduced into a hot furnace and which are to be heated at a definite rate, known to avoid distortion, to a definite number of degrees above the critical and then signalled ready for quench.

Such programs are usually operated by means of a clock-driven cam, cut to the correct curve so it pushes the control lever on the pyrometer up at a desired rate. The control then operates so that the temperature in the furnace closely follows the control lever as it goes up. Reaching the correct maximum value, a contact may be closed which flashes a warning light, either immediately or, by delayed action, after a correct soaking period.

SMOOTHER CONTROL *with the* DEOSCILLATOR



● The effects of lag conditions can be overcome and fluctuating control smoothed out by using the DEOSCILLATOR. This is an auxiliary unit that gives an anticipating effect to the action of any regular automatic temperature control pyrometer.

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● The installation at the left is in a well-known eastern wire mill.

● Definite savings can be made by improving control. You should investigate the possibilities offered by the DEOSCILLATOR.

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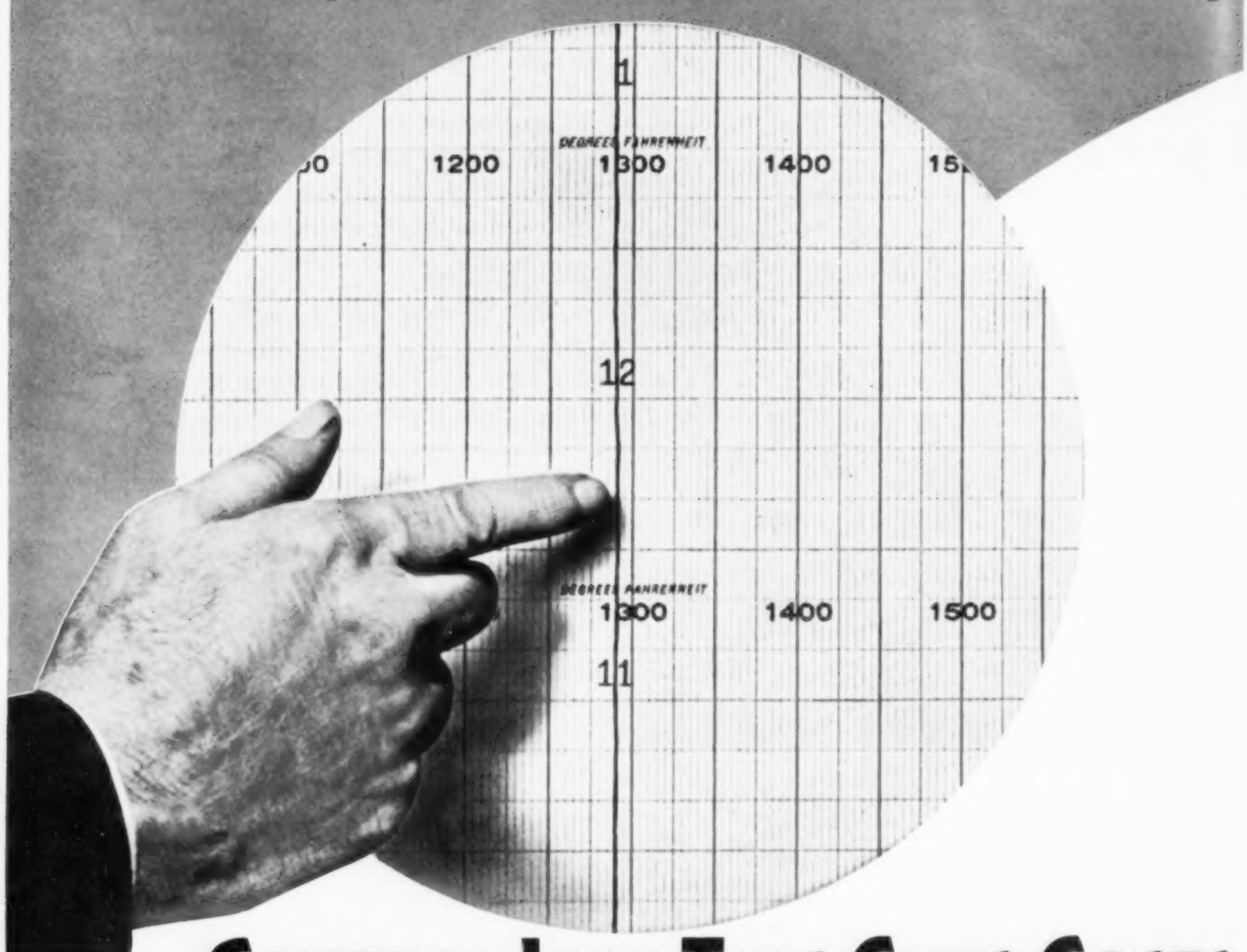

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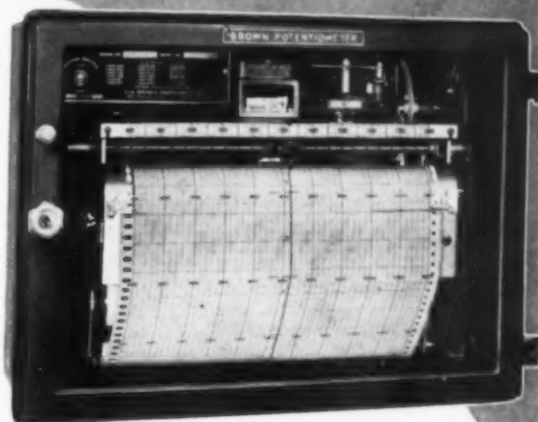

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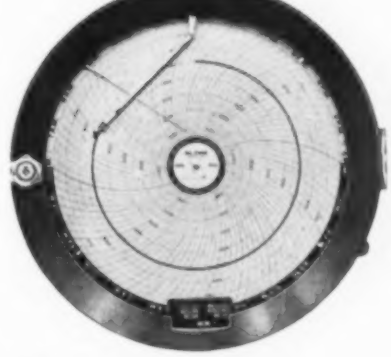

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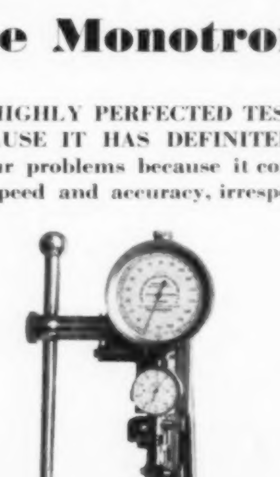

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WELDING AND CUTTING

TABLE OF CONTENTS ●

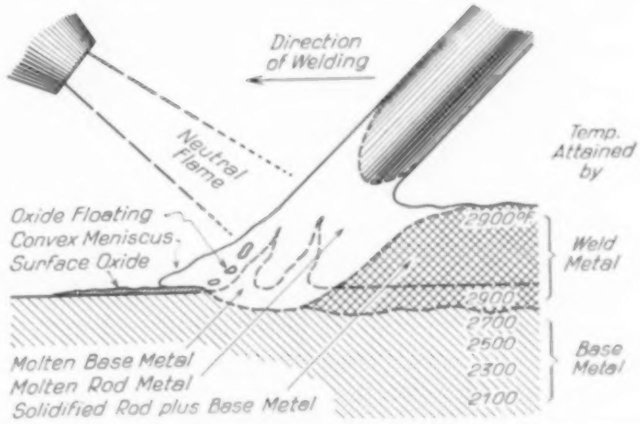
ADVANCES IN . .
OXY-ACETYLENE
WELDING . . . . .

PROFOUND changes in the oxy-acetylene process for welding plain carbon steel have occurred in the last few years, greatly increasing the speed of the operation and simplifying the technique to the point where machine welding will doubtless become possible, without any sacrifice in that high quality of joint which has always been its outstanding virtue.

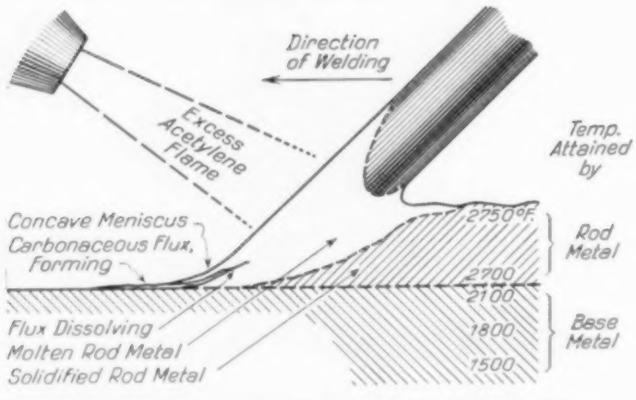
Brief recital of the characteristics of welding with a "neutral flame" in an abutting vee of steel plate, (the recommended standard practice prior to 1930) is necessary to establish a background for the reader. The sketch below is taken from H. S. George's paper in *Journal* of the American Welding Society for July, 1932, and illustrates the essentials. The plates are each beveled so that when butted they form a trough having an included angle of 90° to insure "fusion" and "penetration." This means the progressive melting of a layer of steel at both sides to the bottom of the joint, an intimate mixing of this molten metal with that coming from the welding rod, holding this puddle in a highly liquid state until any trapped oxides or scale can float to the top and move to the solidifying edges of the advancing puddle.

It is obvious that the above requires the manipulation of flame and rod in coordinated movements, oscillating and advancing — movements quite difficult to reproduce mechanically. While this is not the only reason, satisfactory automatic welders have not yet been developed (except for some highly specialized operations like longitudinal joints on thin-walled tubing), and this has handicapped the process in the quantity production of machine or structural parts.

Another characteristic of the process is that a relatively large volume of metal is kept in a liquid condition with a somewhat diffuse flame (as compared with the concentrated heat from a welding arc) despite a rapid conduction of heat



Fusion Welding (Backward Method) Showing How Surface Oxide Is Floated Off



In the Self-Fluxing Process, a Carbonaceous Flame Reduces Surface Oxide, Carburizes the Metal and Produces a True Weld at Low Temperature

back into the cold base metal. This means not only a deliberate rate of progress but the absorption of an undue amount of heat into the adjoining structure, to its detriment by internal stresses and warpage.

The counteracting advantages are the simplicity and portability of the equipment and its ability to serve as an all-purpose tool for welding or cutting all commercial metals.

Naturally a great improvement could be effected in the economics of the process if the heat could be more concentrated and the operation performed at a lower temperature. The latter object had been already achieved by the development of bronze welding, so called, where a low melting alloy rod and flux was used in place of steel welding rod, and a true weld effected with steel at temperatures just below its melting point. (This was a modern adaptation of the old brazing process.) It remained to discover that similar fluxing could be done with carbon deposited from the welding flame, and similar low temperature welding effected between carburized surface of the steel to be joined and superheated steel from the welding rod.

The essentials of this self-fluxing process are sketched in the second diagram from Mr. George's paper. The time-honored "neutral welding flame for steel" is abandoned; a definite excess of acetylene is required, ordinarily enough to give a luminous feather surrounding the inner cone and twice its length. This deposits some carbon along the advancing borders of the heated area, and this carbon acts as a flux — that is, it reduces light scale or rust and bares clean iron. As this clean iron surface gets hotter and hotter, it absorbs carbon from the impinging carburizing flame, until a surface layer 0.001 or 0.002 in. thick may have up to 4.5% carbon (the eutectic mixture) and this skin actually melts when at 2100° F., some 600° F. lower than would the soft steel just beneath (and 600° F. lower than the commencement of fusion if the neutral flame were used). At this moment, when the metal appears to glaze, the melted steel from the rod "wets" it, forming a true alloy with the underlying metal (not yet near its melting point) and the excess carbon at the very surface rapidly diffuses away into the puddle of molten metal.

If the base metal were one of the extra strong pipe plates having 0.35% carbon, the welding rod should carry about 0.15% carbon; the above action of the flame will produce a weld containing 0.25 to 0.30% carbon. The special rod also would contain other chemical elements which cleanse the molten metal and insure a fine grain in the as-welded condition, thus simulating metallurgical practice in the steel foundry. Laboratory welds of this sort have outpulled plate of 90,000 psi. tensile strength; their ductility by the free bend test ranged from 20 to 25% as-welded,

Fixture for Rapid Welding with Flame Containing Exce Acetylene, Wherein an Auxiliary Flame Heats the R

and 40 to 50% in the normalized condition. (In the older practice, 15% stretch on free bend denotes sound, tough weld metal).

This new method has been studied most in connection with the welding of several thousand miles of oil and gas pipe lines. Representative figures may be taken from one line of 24-in. pipe made of steel containing 0.25 to 0.35% carbon and having 70,000 to 80,000 psi. ultimate tensile strength. Specifications required that failure of tensile coupons must occur in the pipe wall or, if at the weld, at a stress greater than 64,000 psi. Of 56 coupons tested, only 7 failed in the weld, and their average tensile strength was 72,900 psi. On another similar line 144 coupons bent an average of 92° before cracking (when the outside of the weld was stretched) or 61° when the inside was stretched.

Of most importance, however, is the gain in speed and economy. The operator merely directs the flame *against* the just-formed joint; is spreads out and forms a carbonaceous film immediately ahead of the advancing puddle. Because oxidation is eliminated, the base metal remains solid and the welding rod barely molten, there are no complicated movements necessary. A larger flame can be safely applied. Furthermore, the included angle at the vee can be reduced to 70° (60° on $\frac{5}{16}$-in. metal and thicker) and the joint needs little or no reinforcement on the outside. This saves at least 25% of the welding rod and gases. The net result of these various factors is that the rate of welding has been doubled, and in some cases trebled, over rates obtained with the older technique.

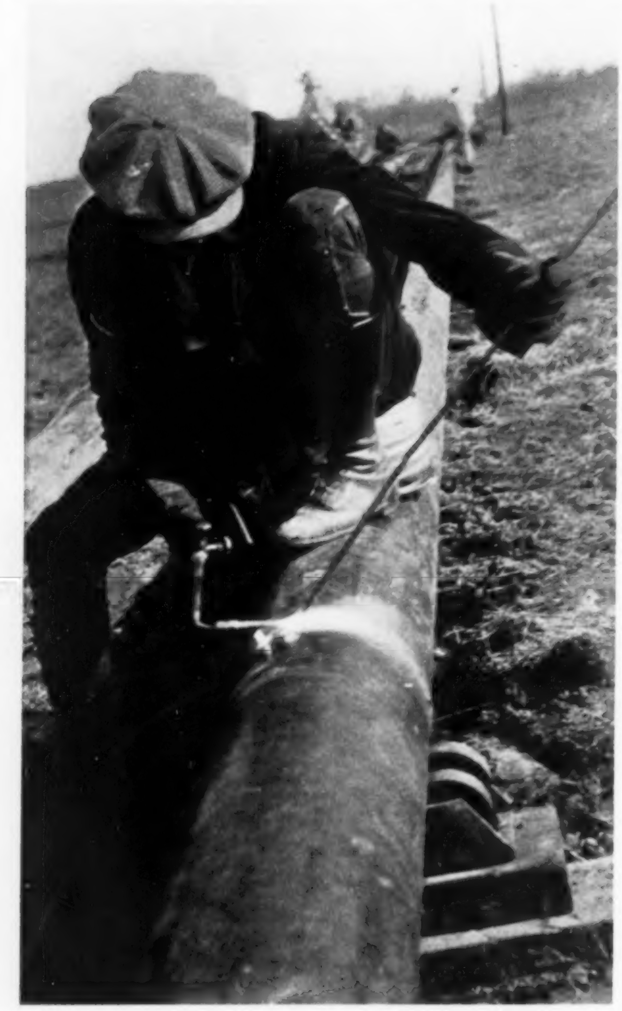
Economies are illustrated in figures gained from two 10-in. pipe lines, laid by equally experienced and well-organized crews. One was 500 miles long; made by the standard neutral flame welding methods it took 20 operators (four on relief) who made 1.4 joints per man-hour, and used 42 cu.ft. of gases and 3.5 lb. of rod per joint. The other was 200 miles long, and made by the newer self-fluxing method, using a carburizing flame. Five operators (one on relief) were employed; they made 3.4 joints per man-hour, and used only 18 cu.ft. of gases and 1.5 lb. of rod per joint.

While Using a Multi-Flame Blowpipe, the Main Flame Is Directed Against the Puddle; The Auxiliary Flames Preheat the Vee Ahead

Owing to the simplified technique, the workmen are much more readily trained. Furthermore, it is possible to devise manual aids, such as the one illustrated on page 140, where the carriage steadies the blowpipe tip, an auxiliary flame preheats the rod, and the rod itself rides along the joint in a holder with lifting device to raise or lower it at will. Such a simple equipment frees one of the operator's hands and relieves fatigue. Strangely enough, workmen experienced with the older technique deride and shun such devices, calling them "Rube Goldbergs"; thus do irrational prejudices frequently halt progress. One guesses, however, that this device is the forerunner of a badly needed automatic oxy-acetylene welder.

Another advantage is that excessively thin steel can be welded, because it is not melted. An instance is butt joints in the chrome-molybdenum tubing used for aircraft; wall thickness is as low as 0.035 in.

Tests on joints, as welded, developed tube fractures in the slightly softened region near the weld (as is usual) at about 95,000 psi. tensile strength. After sample joints were heat treated in a way which developed tube strengths of 125,000 psi. and 150,000 psi. respectively, fractures all occurred 3 to 4 in. from the weld. When some plates of this same alloy steel (S.A.E. 4130) were welded, the reinforcement ground down smooth, and the joints reduced in section, the test pieces broke in the weld at about 80% of the unit strength of the heat treated base metal, with silky, homogeneous fracture, thus



Welder Using Multi-Flame Blowpipe on a Pipe Joint. Note that welding is in a backward direction, and flame is nearly tangent to surface

showing that the weld metal is quite susceptible to heat treatment.

No specialized equipment (that is, blowpipe) is required for welding with a carbonaceous flame. Welding is backhand — rather than forehand as has been usual with oxy-acetylene welding. Doubtless this fact is responsible for much of the increased efficiency, as the hottest portion of the flame is directed almost constantly against the end of the welding rod, increasing its rate of melting, and when the operator manipulates the rod by hand, the preheating flame desirable on such semi-automatic fixtures as shown on page 140 is unnecessary.

Transfer of heat from the slightly luminous flame is principally by convection, and this sets the practical limit for speed of welding. Recent attention has therefore been directed toward a blowpipe which produces two auxiliary flames which strike either side of the joint about 2 in. in advance of the focus of the main welding flame, preheating the metal to a dull red heat — approximately 1000° F. Manipulation of rod and blowpipe is reduced to straight backward and forward "accordion" movements about 1 in. long in the line of the joint. The technique may be visualized from the movie strip on page 141.

With this improvement, the speed of welding vee joints in the down position is increased another 25% over the rates attainable with the single flame blowpipe; the limiting factor now is the speed of melting down the welding rod. It would appear, therefore, that even better results will be obtained in an automatic or semi-automatic fixture where the main flame is supplemented by auxiliaries not only below, to preheat the vee, but above, to preheat the rod. The development is still too new to make definite predictions, but undoubtedly has the greatest possibilities.

Hard Facing

Increasing interest is being shown in several methods of producing hard, wear resistant surfaces. Hardening with heat from an oxy-acetylene flame is probably the simplest; its greatest present application is for hardening rail ends in main line track (see M. D. Bowen's article in April, 1931). Success of an English machine for hardening gear teeth warrants the investigations now going on as to the possibility of hardening the bearing areas on crankshafts.

Another obvious application is a metal overlay, welded on, such as the stainless steel surface on turbine runners photographed on page 145. Welding rods of high carbon steel, with or without chromium, and Hadfield's high manganese steel are also available. Even better rods are stellite (alloys of cobalt, chromium, and tungsten or molybdenum) which is hard and wear resistant at temperatures in the red heat range, 925 to 1550° F. It is welded on by a simple adaptation of the self-fluxing process described above. Hence its success on machinery for handling hot coke and cement clinker, for facing of rolling mill guides, and for hot shears. A ring of stellite on mating surfaces of exhaust valves and valve seats has been adopted as standard practice by three prominent bus and truck manufacturers; reports have it that such valves are in perfect shape after 150,000 miles, even though low grade and doped gasoline is used.

IMPROVED ARC WELDING AND ELECTRODES

WHILE there is nothing to record in the way of revolutionary changes in the principles of arc welding, there have been a multitude of improvements in the equipment. This, coupled with the better understanding of the fundamentals of the operation and an appreciation of the meaning of procedure control, has resulted in a steady improvement in quality and decrease in cost of the work.

Portable direct current generators, one welder for each operator, driven either by electric motor or by gas engine, are now almost universally favored. These welders have been refined in every detail, trim, efficient machinery. Recent interesting auxiliaries are remote control devices and meters which register the amount of time the correct welding current is in play.

Carbon arc welding has also taken on a new lease on life, especially for those gages of sheet or light plate which can be melted at the joint without the addition of welding rod, or for copper or galvanized iron to be welded with phosphor bronze. In automatic welding a powerful aid has been discovered in the form of a strong magnetic field thrown about the electrode, which concentrates and directs the arc stream.

Automatic and semi-automatic welding has been rapidly developed into almost infinite detail. Given a successful mechanical and electrical control of the arc (which was developed several years ago) it may be applied to various fixtures and motions which will serve to weld almost any joint in production, from pipe and tanks to barrels, frames, structural members and motor parts. Attention is now being given to handling equipment, for several surveys of busy departments show that the welding operators are waiting for the work to be adjusted more than half the time.

Improved Welding Electrodes

Important recent advances in electric arc welding have come about from improvements in electrodes. This statement is certainly true as to engineering applications. Sound technique had developed reliable methods with "bare" electrodes for static structures, but modern coated and covered electrodes have enabled the welding operator to produce joints good enough to pass the rigid specifications of vessels carrying alternate stresses and high pressures.

It is rather a curious circumstance that the American arc welding industry was using bare electrodes almost exclusively up to five years ago when our English cousins were doing perhaps 90% of their work with mineral covered electrodes. Bare electrodes were favored by the workmen, because the heat from the arc is concentrated in a small area and the metal from the electrode joined with the base metal no matter whether the seam were flat, vertical, or overhead.

They are also cheaper and hence appeal to the penny-wise purchasers.

Unfortunately, however, the weld metal from bare electrodes is not well protected from the ambient atmosphere, with the result that it absorbs more or less nitrogen and oxygen, and the result is metal hard and moderately strong, but lacking in ductility, even when deposited from the best low carbon steel or iron rod.

It must not be supposed that bare-electrode welding, properly performed, is unreliable. In fact, our most unbiased information as to the performance of welding operators in structural shops, and the strength and uniformity of welds made under procedure control, was secured by the five-year research program of the American Bureau of Welding on this very subject. H. M. Priest summarized the results in METAL PROGRESS for December, 1932. Tension tests on butt-welded joints show that qualified operators have no difficulty in making welds in structural steel with bare wire whose average strength is 52,000 psi. and none falling below 45,000 psi. Elongation of only 8% in 2 in. over the joint is not so satisfactory. The factor of safety commonly used by designers is 3½, and applying this to the minimum values reached in the Committee's program, the unit working stresses for design purposes recommended are 11,300 psi. in shear, 13,000 psi. in tension, and 15,000 psi. for welds in compression.

These results are of the utmost importance in confirming the uniformity of structural welds, and have been responsible for a truly remarkable growth of welded frames for buildings and machinery, and for reinforcing of overworked bridges.

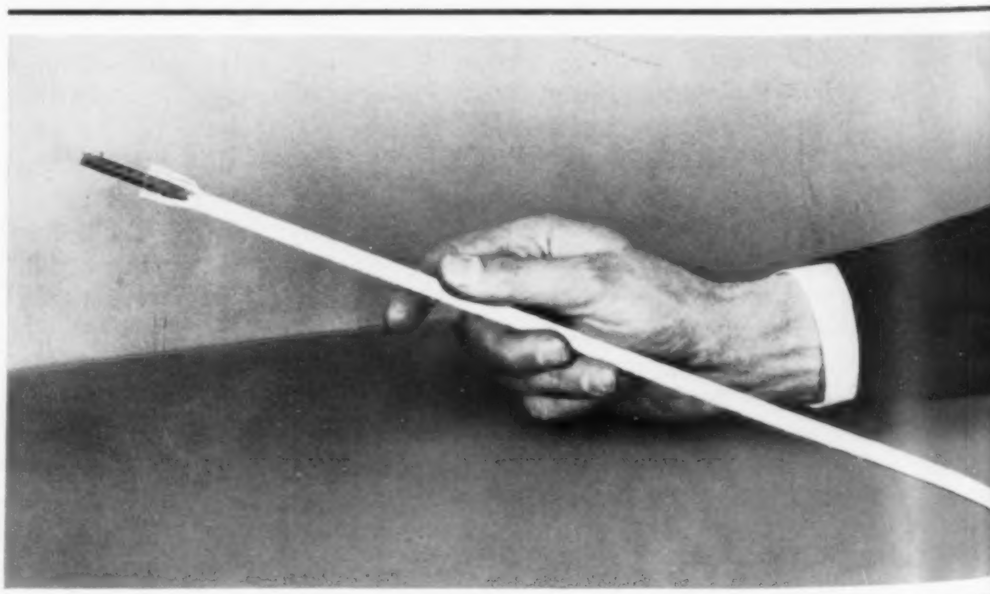
Some have advocated the use of weld metal considerably stronger but less ductile than the base metal, believing that in the event of overpowering stress, failure would occur in the base metal rather than the joint. Without arguing this point at length, it may be said that the recent move toward coated and covered electrodes is designed to give weld metal as nearly like the base metal as possible, as far as strength, ductility, corrodibility, and other ruling physical properties are concerned. The ideal, of course, is a joint indistinguishable from the material being joined, and the simplest case is the most important, namely, welds in soft carbon steel plates and shapes.

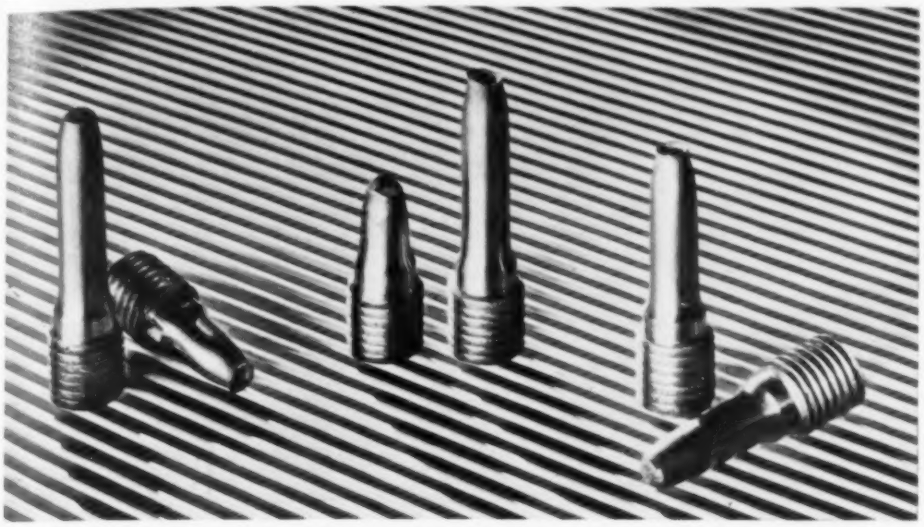
In the oxy-acetylene process this matter of matching composition has been solved by clever alloying of the welding rod. More oxidizable metals like manganese and silicon are present in excess, and a part of these combine with any oxygen picked up during melting and puddling and readily slag off, protecting the carbon; the result is a sound weld of controlled carbon.

If higher carbon steel is used as bare electrodes, much of the carbon is burned out during the process, leaving weld metal of uncertain composition, and deficient soundness and ductility. One way to prevent this change in nature of the electrode metal during its transfer into the joint is to shield the arc from the oxygen and nitrogen in the ambient air by an envelope of inert or of combustible gases (as indicated by the oxy-acetylene process and the atomic hydrogen arc). The result is somewhat similar to operating an arc inside a bonfire.

Such reducing gases can be blown down about the arc, or provided by some fuel fed into the arc, or by a combustible coating on the electrode. Such methods have been commercialized (although the wider use of carbonaceous materials and fiber wrappings has been hampered by patent litigation) and have done what was

Electrode With Covering Split at End to Show Its Relative Thickness





Standard Tensile Specimens Machined From All-Weld Metal; Fractures Fine-Grained and Full Cup. At left is low nickel steel with 59,000 psi. yield strength; in center is medium nickel steel with 72,000 psi. yield; at right is molybdenum steel with 54,000 psi. yield strength

expected of them, namely, produce a mild steel weld much cleaner of oxide particles, much sounder, and containing less of the hardening nitrides — in short, a more ductile joint. A most important concurrent advantage (and one which looms largest to many metal fabricators) is a notable gain in speed. Much more energy can be put into the arc without causing it to become unstable, and the rate of deposition of weld metal (and the penetration into the base metal) is correspondingly increased.

Specific data are quoted by A. F. Davis, to the effect that the limit of hand welding with bare electrodes (200 amp. and 20 volts, with ¼-in. wire) has been increased to as much as 400 amp. and 30 volts with the same size of covered electrodes. Rate of melting rises from 5 lb. of electrode per hr. to 10 lb. Speed of welding has also been doubled (for instance, to 44 ft. per hr. on lapped ⅜-in. plates). Most notable from a metallurgical viewpoint is a fine-grained deposit, clean, and free of visible nitride needles. Butt-welded structural plates, tested in tension, break in the base metal, so our idea of the properties of the actual joint must be derived from tests on all-weld metal specimens. These will develop 65,000 psi. ultimate strength, and 20% elongation in 2 in. (quite an improvement over the figures for bare wire quoted above). Ductility as measured by stretch around the outside of a free bend test on a welded joint in ordinary plate shows elongations approaching 50% when bent flat without cracking, whereas weld metal deposited from bare electrodes will barely stretch 15% before cracking.

It can readily be appreciated that this combined gain in physical properties and speed of welding has been responsible for a remarkable acceptance of the modernized process by engineers and production men for the fabrication of large pipe and other pressure vessels (both of mild steel and of the stronger medium steel), and machinery parts of all sorts. Approval by the Navy for extensive use of welding on the hulls of the new warships is in itself a guarantee of quality.

Obviously there is another way to protect arc welded metal from deleterious reactions with atmospheric gases, and that is to coat the electrodes with a mixture containing some non-combustible materials which are fusible and slag-forming. In fact, this has been the preferred method of operating in England for many years.

Coatings Which Produce Much Slag

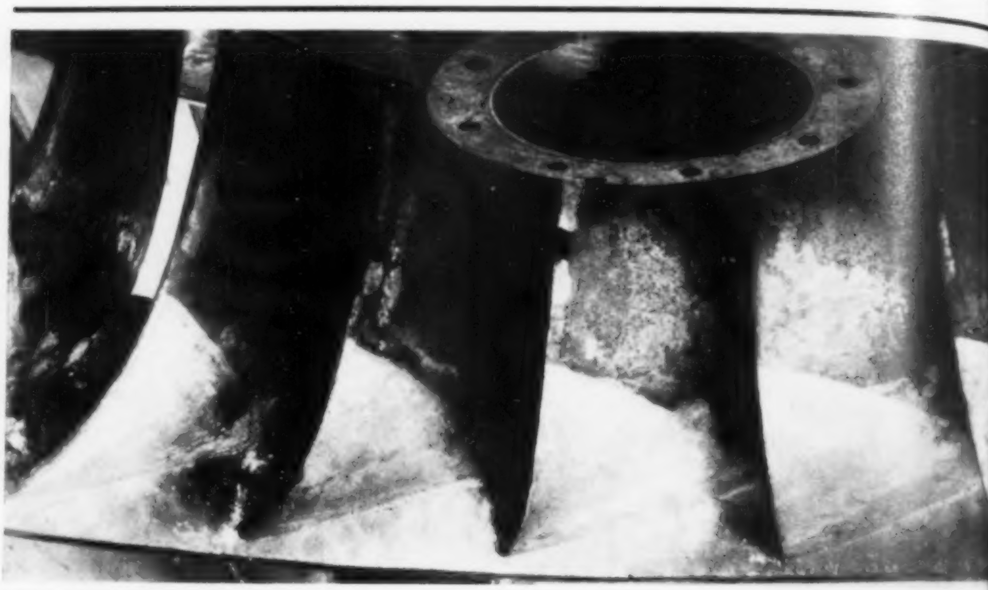
In this country we have developed the idea further, not only for welds in heavy mild steel plate for high pressure drums, but also for the low alloy, high strength constructional steels now attracting so much attention. Such coatings may be merely inert protectors of the metal electrode, which in that case is a close match in composition of the plate being welded, or they may contain alloying elements which enter the joint during welding. In the latter event the electrode may be a mild steel (if a low alloy steel is to be welded) and the physical properties of the steel to be joined are approximated by alloying from the edges of the joint, supplemented by metals furnished by the coating.

Both methods have been commercialized. It can be seen that metallurgical and chemical skill of high order is necessary to devise such coatings, which, in addition to their chemical functions when molten, must be non-conductors of electricity, easily and completely detached

from the cold joint, and impervious to atmospheric gases.

Many such coated electrodes and their slags have one important characteristic, at once a disadvantage and an advantage, namely, great fluidity in the molten state. The disadvantage is that it is more difficult to make this highly fluid metal and slag stay in position in vertical and overhead joints; but at the same time, because of the greater fluidity, the metal once positioned should be more uniformly dense and sound and have less chance of cold shuts or overlaps on the parent metal. The work, therefore, should be moved and placed so the welds can be deposited in the down position. Where heavy fillet welds are to be made, the "bare wire" operator can normally build up the complete thickness of fillet as he goes along, whereas the same fillet from an electrode coated heavily with mineral is made by depositing a number of thin layers until the proper thickness is reached. Each of these layers grain-refines the layer beneath. The total time is usually less because of the high rate at which the coated electrode deposits its metal.

Fine grain and proper chemical composition are therefore responsible for surprisingly high ductility in the joints, even when the steel being joined possesses 100,000 psi. tensile strength. Aside from theoretical advantages, this has the very practical advantage that such a ductile weld will yield readily against internal stresses set up by the welding heat, even without the customary peening operation, and this smooths out stress concentrations which would cause a stiffer joint to crack even before it could be given a stress-relieving anneal. It is not to be inferred that the most ductile weld will not need a stress-relieving heat at about 1100° F., but that the necessity for such an operation is due as much to stresses set up in the near-by base metal by the heat, as to residual stresses in the very joint.



Hydraulic Turbine Runners Which Wear Rapidly From Cavitation Are Protected by a Layer of 18-8, Welded on and Ground Smooth

Publications by J. C. Hodge may be consulted as to the properties of joints made with slag-forming electrodes with automatic welding heads in pressure vessels with walls up to 4¼ in. thick where the weld metal is designed to match the plain carbon boiler and flange steel. Tensile tests on standard specimens cut out of weld metal from such joints easily equal the best metal in boiler shells. Toughness, as measured by Charpy impact, is even superior. Chemical composition is also a good match (see table below).

Uniformity and high quality are proven by the record of X-ray inspection. Since the Babcock & Wilcox shops have been equipped for welding, about 1400 steam boiler drums, 500 pressure vessels, and four major penstock constructions have been undertaken, on which about 225,000 ft. of welded seam has been X-rayed. Defects discovered have been very few and are

	Weld Metal	Firebox Plate
Physical Properties		
Tensile strength	67,000 psi average	55,000 to 65,000 psi.
Yield point	52,000 psi. average	30,000 psi. average
Reduction of area	40% average	
Elongation in 8 in.	30% average	25%
Charpy impact range	20 to 45 ft-lb.	
average	28 ft-lb.	20 ft-lb.
Endurance limit	30,000 psi.	31,000 psi.
Chemical Properties		
Carbon	0.08 to 0.15%	0.25% max.
Manganese	0.30 to 0.60	0.30 to 0.50
Phosphorus	0.04 max.	0.04 max.
Sulphur	0.045 max.	0.04 max.
Nitrogen	0.020 max.	0.010 max.

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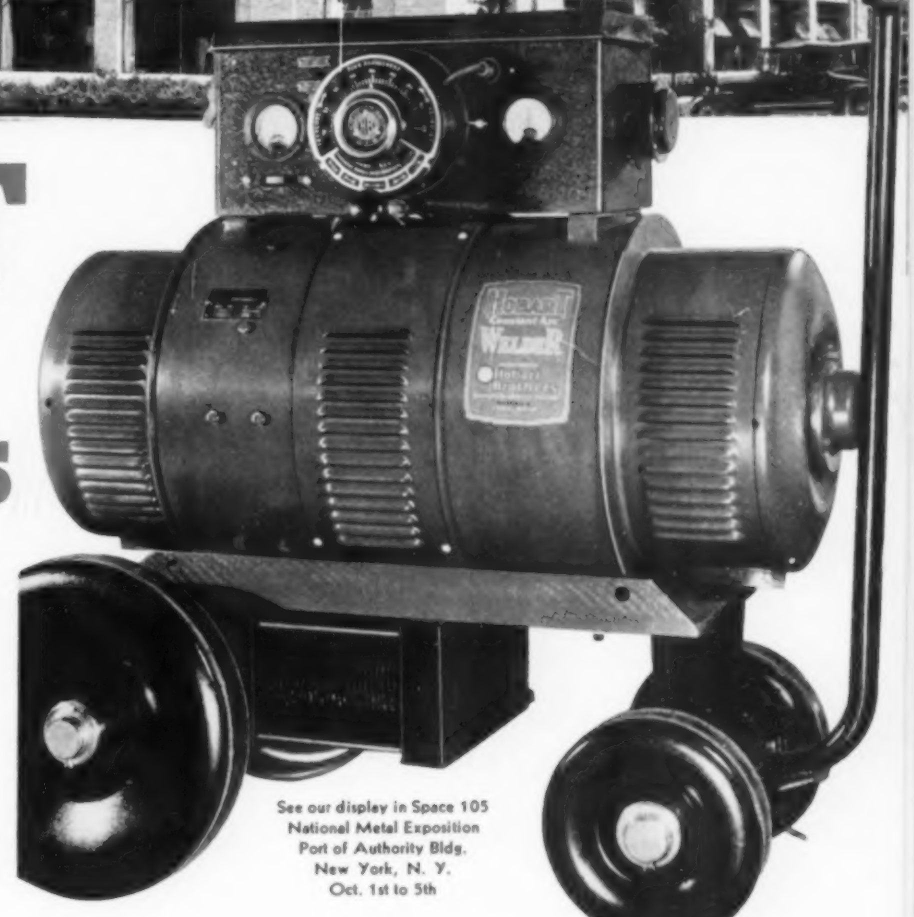

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steadily decreasing in number. Under the rigid requirements for pressure vessels, many of these repairs have been made in places which did not appreciably detract from the quality of the original joint. Experience in other shops making class I pressure vessels verifies these trends.

Inspection of the table will indicate one interesting feature of welds made under slag-forming electrodes, namely, that the tensile properties (especially yield strength) are better than would be expected from the contents in carbon and other hardening elements. This is due to the extremely fine grain size obtained in multiple beads, and the slightly higher nitrogen.

This anomaly is even more evident in weld metal which becomes slightly alloyed by reactions with the slag and base metal. Take for instance the following data furnished by J. H. Deppeler of all-weld metal deposited in a heavy joint of manganese-molybdenum steel.

	Weld Metal	*Alloy Steel Plate*
Physical Properties		
Tensile strength	*88,000 psi.*	*99,000 psi.*
Yield point	*76,000 psi.*	*66,000 psi.*
Reduction of area	*52%*	
Elongation	*23% in 2 in.*	*15% in 8 in.*
Rockwell hardness	*C-15 to C-18*	*C-14*
Chemical Properties		
Carbon	*0.09%*	*0.15%*
Manganese		*1.60%*
Silicon		*0.40%*
Molybdenum	*0.50%*	*0.40%*

Evidence is available that weld metal of this sort, deposited in narrow grooves, mingles with alloy from the adjoining plate and matches it in high quality; joints in ¾-in. material, for instance, developed the full strength of the plate.

Stainless Steel Electrodes

Welding of the various high chromium and high chromium-nickel alloys may be done with the oxy-acetylene flame, using metal of the same composition as the base metal and protecting it from chemical change with a properly adjusted flame and a correct flux. These two protectives are supplied to the electric arc in the form of a correctly compounded coating.

In many of the alloys the carbon must be under strict control, and electrode coatings in such cases must be free from all carbonaceous material. Coatings compounded of lime, silica, clay, and various chemical salts are trade secrets of the manufacturers. Ingredients are usually mixed with the minimum of water, applied to the cleaned wire, and then carefully dried and baked. Coloring matter is used to distinguish between the various alloys.

Electrical characteristics of these high alloys are sometimes unfavorable to the welding arc, and while such a thing as sputtering can be put under control by the coating, it frequently cannot be entirely eliminated. So successful are some of these coatings that weld metal deposited from them is superior to commercial 18-8 in resistance to accelerated corrosion tests.

Any analysis which can be drawn into wire can be converted into electrodes which deposit sound metal of substantially the same chemical composition (barring a loss of about 1% of chromium). The finer diameters of wire, even down to $\frac{1}{16}$ in., are of importance, for many industrial applications require the welding of thin sheet. Electrical resistance of the alloys is usually several times that of low carbon steels, so short electrodes (usually bare at the center for gripping) are the rule.

Leon C. Bibber has written, in The Book of Stainless Steels, about an extensive investigation of welding of 18-8 by the U. S. Navy. According to him, carbon can be kept down to 0.07% in the deposit, and no nickel is lost in the operation. Chromium, as mentioned, drops about 1%, and this is allowed for by using a higher chromium electrode wire, or by replacing it with more chromium from the covering. Nitrogen (which runs higher in the chromium alloys made in electric furnaces than in plain steels) is not appreciably increased in the arc.

As to tensile properties, 18-8 weld metal in flat seams has 75,000 psi. ultimate strength and 25% elongation in 2 in., as compared with 85,000 psi. and 60% respectively for commercial 18-8 plate. Figures are slightly less favorable if samples are cut from vertical and overhead seams.

Corrosion problems frequently reside in metal immediately alongside the weld rather than in the weld metal itself. This opens the whole question of "weld decay," which has been so extensively discussed. Suffice it to say here that this problem (together with the air hardening, grain coarsening, or embrittling of other alloys by the welding heat) is characteristic of the base metal itself and the way it reacts to heat. Solutions of such problems, therefore, have been derived from studies of the constitution and heat treatment of the base metal rather than from modifications of the welding technique.

FORGING and PRESSING MACHINERY

● Forging machinery has been made more precise and more responsive to operator and this has also been matched by improved cold heading and coining machinery . . . Fast forging has been effected by automatic feed, by ganging into a string, and by doing more work in a single stroke . . . Steels have been improved as to grain size control, in order to stand maximum work and still be easily machinable . . . ●

ADVANCES IN . . .

FORGING PRACTICE

AND MACHINERY

MANUFACTURERS of forging machinery are constantly improving the equipment so that more accurate parts may be made in them at greater speed and with less fatigue to the workmen. Some interesting developments in fast forging by automatic feeders and in multiple dies have also been recorded. Simultaneously furnace builders have come forward with devices for heating the billets more uniformly and with little or no scale. Much has also been learned concerning the mutual relationships between grain size in the steel, its forgeability, and its machinability.

All in all, recent years have been interesting ones for the forging industry and their customers. There has been the above accumulation of factors making for excellence and economy. Progress has really been necessary for self-preservation, as other portions of the metal industry are also advancing, technically and metallurgically, to a point where forgings are meeting new competition from high test gray iron and alloy steel castings, short cycle malleable iron, and welded stampings.

More Precise Machinery

Aside from the effort of manufacturers to make presses and forging machines quicker acting, handier for the operator and more responsive to him, (matters which increase the speed of production) there is a noteworthy advance in those factors which make for precision in the product.

In all this equipment where heavy pressure is put on the work, either by a squeeze or a rapid blow, the deflections in the frame have to be carefully considered. In forging machines and upsetters, for instance, the frame has been shortened to decrease the amount of metal in tension, deepened to reduce the bending moments, and made into a massive one-piece unit with necessary openings carefully studied to avoid stress concentrations. An instance was cited by Everett Chapman in the Lincoln Prize Competition where a 70,000-lb. frame for a forging press which stretched 0.029 in. in frame and bed under full 500-ton pressure was redesigned for steel slabs, saving 30,000 lb. of the weight, and, owing to better disposition of metal and distribution of stress, the maximum movement or spring at the dies was only 0.012 in. Of course, parts produced in such machinery are proportionally closer to dimension.

Slides, for carrying moving dies, must be long and as narrow as safe stresses permit, to reduce the tendency to rotation ("cocking") and properly engineered to take care of the moderate increase in temperature within the machine during operation, and to avoid undue wear from entrapped scale. Motions are also designed so the dies can grip the hot blank long enough to gather the metal into depressions, but not an

instant longer, else there will be an immediate jump in the cost of heat-checked dies. Modern constructional steels and alloys also lend themselves to the improved machinery in such ways as heat treated steel castings for frames, and highly stressed operating parts, high test and close grained gray iron for wheels, slides and guide plates which must resist wear, steel slabs flame cut to shape for yokes, nickel bronze bushings for high pressures, and ground forged pins and cams for main bearings, and forged steel tie rods and bolts, shrunk in place.

Such items as the above are responsible for an increase in accuracy of performance which sharply differentiates the precision forging of today from the best available only a few years ago. These forgings, whether made hot, cold or at intermediate temperature, are not only accurate in dimension, but are quite free from parting line flash (due to dies springing open under pressure) and may be made with deeply pierced holes, accurate to line, or split in a way that formerly was done only by sawing.

Another advance in accurate forging has come about during the last three or four years by the use of solid rather than split dies. The work is restricted to fairly simple shapes (such as the grinding balls for which solid dies were first used) and those which have no undercut or channeled portions which would prevent them from being knocked out of a solid die. Likewise the dies must be blown clean of cooling water with compressed air just before the hot slug enters them, else a steam pocket will form and produce an unfilled forging.

Good engineering throughout the entire forge plant is necessary for most accurate results. Furnace builders have cooperated with furnaces capable of heating the billets to forging temperatures without scale, either by electrical heat in controlled atmosphere, or rotary or slot-type furnaces fired with diffusion combustion burners. (Much might be said about the necessity for more adequate furnaces in many forge shops.) Temperature control is essential, in order that steel and dies may not be overheated, yet the blank be uniformly hot enough to fill properly. Another powerful aid to good forging is steel with proper grain size.

Similar considerations affect the accuracy of drop forgings. A. M. Steever analyzed this problem in an article for METAL PROGRESS in November, 1930, as it applies to a simple forging, 8 in. by 2 in. made to a tolerance of $\frac{1}{64}$ in. (about 0.016 in.).

The normal clearance between the ram and guides of a steam or board drop hammer is 0.006 in. The twisting action of the ram due to this clearance, if the die impression is off center, is

Transportation Industries Have Always Insisted on High Grade Forgings (Photo by Rittase)

to the clearance as the length of the forging, front to back, is to the width between guides. Therefore, if the distance between guides is 20 in., 0.0024 in. variation is probable in addition to guide clearance. There must also be some clearance between the frames and anvil to prevent the frames from "walking upward." This clearance is about 0.001 in. Another cause of variation is temperature. As the work goes steadily on, the dies normally would increase 300° F. in temperature. This heat passes progressively through the upper die to the ram, and through the lower die to the sow, the anvil and to the frames. Due to this temperature differential, each part is tending to loosen its connections with the next part; for instance, the dies expand from their dowels, the dowels loosen, and so on. The total of these variations due to temperature accounts for another 0.001 in.

Adding together all the expected errors due to play in the hammer gives 0.0104 in., leaving but 0.0052 in. (or one-third of the originally specified tolerance) to care for variations in forging temperatures, wear of dies, normal wear in the hammer, and all other variables. This is a very small margin. The makers of hammers are improving the design of their equipment, but finished forgings can be made to fine dimensions only by coin pressing or cold hammer restrike. The expense of this would be warranted where expensive machining operations are saved.

More accurate cold heading machinery is also being constructed along the same general lines of improvement outlined above. One most interesting proposal is to synchronize a wire drawing machine with a cold header, thus enabling the bolt maker to purchase hot rolled rod at a considerable price differential; give it an accurate sizing by reducing it say $\frac{1}{32}$ in. in diameter in a tungsten carbide die, and feed it directly into the header. Such a plan should also cut down the scrap made before the header can be adjusted to a new coil of cold drawn wire of slightly different diameter, and also should deliver cold drawn rod to the heading die, somewhat warmed and properly coated with lubricant (something which may be damaged or dirtied during the trip from drawing plant to bolt factory).

A review of methods used at the Ford plant for speeding up the output of forging machines was published in METAL PROGRESS as recently as last May, so it is hardly necessary to do more than mention the lines along which it is progressing. Faster forging comes about by reducing the number of blows necessary to change the bar into a gear blank, for instance, or by automatic machines for feeding the bar through the progressive die impressions, so that each die is operating on each stroke. The first plan involves upsetting in a closed die in a single stroke; the limitations here are the somewhat simple shapes which may be produced and the resistance of the die — work must pause after six or eight forgings are made in order to cool the dies.

The automatic feeder is on a machine for upsetting a gear on the end of rear axle drive shafts. It works in connection with a transfer table leading from a continuous heating furnace. Obviously the main limitation here is a volume of production which will keep such a unit operating a large enough proportion of the time to warrant the expense of such specialized equipment. Three men are required, and best production in an 8-hr. day has been 5600 axles.

Automatic feeding of gas engine valves through upsetters has also been tried at more than one plant, but indifferent success is reported. Other efforts to improve production on valves have been to redesign the dies and select a steel which can be gathered into the required shape in a fewer number of strokes.

Forging of two or more small pieces simultaneously under a drop hammer, later to be trimmed from the flash, is an old story. In the most ambitious effort in this way known to the writer the die had 12 roughing and 12 finishing impressions cut in it, and was operated by two forgemen to make simultaneously two strings of six rocker arms for a gas engine. Expected maximum production was 240 forgings per min., but apparently this is somewhat beyond the capabilities of multiple dies, as the operation was abandoned.

Still another promising method of fast forging, developed by A. O. Smith Co., utilizes a long bar, heated from end to end, and fed step by step forward through a forging press, having three dies properly spaced. The first is a breakdown impression, the second is a forging die, and the third is a trimmer.

All these schemes for multiple forging involve a problem in trimming — if forgings are to be cut out of the flash as a gang, the drop in temperature from the last forging step to the trimming operation must be constant, else variable cooling contraction will misalign the work. This means forging and trimming at closely controlled temperatures — not always an easy thing to insure in plant operation!

Another limitation of fast forging hinted above is the heat resistance of the dies. All modern forging machinery can operate (mechanically) at a steady rate which will ruin the dies from heat checking in short order. Until this detail is taken care of by the alloy steel metallurgists, it will always be necessary to slow down the machines to a point where lost production balances cost of more rapid die replacement.

Steels for Forging

Messrs. Cederleaf and Sanders have made a notable contribution to the rational study of "fiber" and the properties of forging. These are more properly called flow lines, for they appear in a deeply etched cross-section of a forging and are suggestive of the way the metal flows under pressure to fill the dies.

Their studies on transmission gears indicated that the flow lines were less and less in evidence as the metal was more and more strongly compressed in the dies, and that these strongly compressed steels normalize more uniformly and can be machined at greater feeds and speeds.

This indicates that the forging machinery and all preliminary operations must be unusually precise. In an effort to get a well-filled die it is important, for instance, that the slug be not a bit too large or a bit too cool, else very heavy strains will be set up in the machinery, and result in larger repair bills in the forge shop than the saving in enhanced machinability.

Grain size of the steel also has a pronounced effect on its forgeability, either hot or cold. As pointed out by R. L. Wilson in August's METAL PROGRESS, a steel which retains its fine grain at forging temperatures will not flow as easily as one which is coarse, and this will require more blows under a hammer or more power in a press or forging machine. On the other hand, it is stronger at temperature and will endure a high deforming rate without developing defects.

Structure and uniformity, in the opinion of H. B. Pulsifer, are more important for cold heading than grain size of the metal. He shows in the March, 1933, issue that steels up to 0.65% carbon may be headed without "interfering too much with the manufacturing routine" provided they contain well-developed ferrite — the ductile constituent that deforms plastically during the operation. Non-ferrous alloys, similarly, should have a preponderance of ductile solid solution comprising the microstructure.

ASK FOR THESE HELPFUL BOOKLETS

Fast-Cutting Steel

Bliss & Laughlin, Inc., offer an interesting technical folder on Ultra-Cut Steel, giving performance records of this high-speed screw stock on automatic screw machines. Physical data and microstructures are presented. Bulletin Ob-42.

New Way to Case Harden

Chapmanizing, the new method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given out on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Metallograph

A new 36-page booklet of E. Leitz, Inc., contains all information on the Leitz large Micro-Metallograph, MM 1. Excellent photomicrographs are reproduced to show its capacity. Special attention is given to the darkfield illumination feature. Bulletin Se-47.

Shielded Arc Welding

Lincoln Electric Co. offers a very fine descriptive booklet describing the process of welding with a shielded arc. Text and illustrations are designed to acquaint engineers with the possibilities of the process. Bulletin Ob-10.

Torsion Impact Tests

Baldwin-Southwark Corp. makes available a folder of technical information on their Carpenter torsion impact testing machine, showing how to operate it and indicating the types of investigation the machine will serve. Bulletin Ob-67.

Shear Knives

An easy-to-read folder of Braeburn Alloy Steel Co. gives reasons for the fine performance records of their shear knives and illustrates the many types of knives available, with recommended applications of each. Bulletin Ob-82.

Induction Drying Ovens

Ajax Electrothermic Corp. tells, in a new folder, how the principle of induction heating is applied to paint, enamel and lacquer drying ovens. Advantages are explained and installations pictured. Bulletin Ob-41.

Grinding Wheels

Carborundum Co. has prepared a handsome, 48-page booklet which is a treatise on the dressing and truing of grinding wheels. All who supervise grinding operations will find it valuable. Bulletin Ob-57.

Pyrometer Accuracy

A thought-provoking folder of Hoskins Mfg. Company explains how the use of Chromel-Alumel for pyrometer lead-wires makes it possible to take full advantage of modern pyrometric instruments. Bulletin Ob-24.

Alloy Steel Data

A helpful collection of data on Hy-Ten alloy steels is offered by Wheelock, Lovejoy & Co. For each type information is presented on uses, heat treatments, properties and shapes available. Bulletin Ob-74.

Heat Treating Baths

The complete line of heat treating baths made by A. F. Holden Company is described in an interesting folder which fully discusses each type and gives general recommendations. Bulletin Ob-55.

Cast Tool Steels

The advantages of cast-to-shape tool steels are told in a series of 4 folders of Detroit Alloy Steel Co., covering their Krokoloy, Carbomang, Castaloy and Martin Steel tool materials. Simply ask for Bulletin Ob-86.

Pyrometer Supplies

Claud S. Gordon Co. offers a large catalog giving prices and descriptions of the great variety of pyrometers and pyrometer accessories carried in stock for quick delivery. Bulletin Ob-53.

Heat Resisting Alloy

Ohio Steel Foundry Co. offers an elaborate booklet covering the production of Fahrite heat resisting alloy castings, illustrating their many uses and giving comprehensive metallurgical data. Bulletin Ob-40.

The Prevention of Rust

"Proof of Results" is the apt title of a new booklet issued by Dearborn Chemical Co. Dozens of photographs, supported by an interesting text, show how No-Ox-Id keeps steel from rusting. Bulletin Mr-36.

Arc Welding Manual

Hobart Bros. offer a new edition of their manual of simplified arc welding. Chapters cover the arc, welding equipment, types of welds, weldability of metals, choice of electrodes, the carbon and metallic arcs, speed and cost of arc welding. A useful book. Bulletin Ob-20.

Conditioned Atmosphere

W. S. Rockwell Co. has issued a folder on their conveyor, belt-type furnace with conditioned atmosphere for handling most metals in bright and scaleless hardening. Advantages are clearly shown. Bulletin Ob-34.

Free Cutting Steel

Jones & Laughlin Steel Corp. has published in attractive booklet form a record of 15 years of research by their metallurgical department into the machinability of free cutting steels. Bulletin Ob-50.

Die Steel Facts

A. Finkl & Sons Co. has collected a great deal of information on their Mo-Lyb-Die steels and Durodi hot work steel, presented in such form as to be a handbook on all phases of the subject. Bulletin Ob-23.

Forging Machines

National Machinery Co. has published a large and very attractive booklet which by excellent illustrations and well written text tells how forging machines are built and why they produce accurate forgings. Bulletin Ob-14.

Reports on Firebrick

Babcock and Wilcox Company offer a very complete set of Service Reports on Insulating Firebrick. These reports contain valuable data on adaptability of refractories and savings possible. Bulletin Ob-75.

Stainless Steel Uses

The wide range of applications of Allegheny Metal, best known of Allegheny Steel Co.'s corrosion and heat resistant steels, is pictorially covered in a new and interesting booklet. Bulletin Ob-92.

Welding Regulators

A new booklet on oxacetylene welding and cutting pressure regulators and regulation problems is offered by the Air Reduction Sales Co. A real engineering treatise on this subject. Bulletin Ob-69.

(Continued on next two pages)

ASK FOR THESE HELPFUL BOOKLETS

Cutting and Grinding
Sun Oil Company have prepared a folder showing cutting and grinding operations with facts on use of oils in these operations. Bulletin Ob-52.

Non-Ferrous Annealing
General Electric Co. describes bell-type furnaces for annealing non-ferrous metals in a new folder which gives many data on operation and performance. Description is from technical rather than sales angles. Bulletin Ar-60.

Thermit Welding
Metal & Thermit Corp. offers a new booklet showing all the possibilities of Thermit welding, explaining the action, and telling in detail how representative Thermit welds can best be made. Well illustrated and clearly written. Bulletin Ar-64.

Hardening at 2500°F.
C. I. Hayes, Inc., describes their Certain Curtain electric furnace for hardening alloy and high speed steels in the range 1850-2500° F. Emphasis is laid on the features of Hayes Certain Curtain atmosphere control. Bulletin Jy-15.

Manual of Pyrometry
Brown Instrument Co. offers an elaborate manual which describes the 50 exclusive features of their potentiometer pyrometer. The book will greatly interest those who must maintain accurate temperature. Bulletin Jr-3.

New Furnace Control
A new and unusual instrument for controlling heating rate of electric furnaces is announced by Lindberg Steel Treating Co. An interesting folder tells how this device "turns down the heat" on any size electric furnace. Bulletin Ar-66.

Bright Annealing
Illustrated bulletin showing various continuous and batch type electric furnaces for bright annealing, copper brazing, strip annealing, wire annealing, etc., also the Ajax Electric Ammonia Dissociator for producing hydrogen for furnaces using a reducing atmosphere is offered by the Ajax Electric Co. Bulletin Ob-43.

Alloy Castings
Michigan Steel Casting Company has a new bulletin which gives detailed information on the properties and uses of their various alloys for resisting stains, heat and corrosion. Bulletin Ob-84.

Optics in Metallurgy
Many uses for optical instruments in metal working are described in a new booklet of Bausch & Lomb Optical Co. Photomicrography is prominent, but this well illustrated booklet shows many other interesting optical instruments. Bulletin No-35.

High Strength Steel
Cromansil steel, a development of Electro Metallurgical Co., has high strength and good ductility "as rolled" and is thus fine for structural applications where its great strength saves much dead weight. Bulletin Je-16.

Uses of Molybdenum
Climax Molybdenum Co. offers a useful 50-page booklet showing the benefits conferred by alloying molybdenum with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Au-4.

11 Stainless Steels
Pertinent facts on 11 different types of Bethadur and Bethalon corrosion resisting steels are presented in a 40-page Bethlehem Steel Co. booklet. Advantages and limitations of each type are frankly presented. Bulletin Fb-76.

Aluminum vs. Corrosion
In a carefully prepared booklet of Aluminum Co. of America, effects of various corrosive agents upon aluminum and its alloys are described in detail. It is an excellent source of information on this subject. Bulletin Sp-54.

Hardness Testing
Men interested in hardness testing may find it worth while to read the recent catalog of Wilson Mechanical Instrument Co. which describes the latest design of Rockwell hardness testers and auxiliary work supports. Bulletin Sp-22.

Big-End-Up
Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Blast Cleaning
A rugged blast cleaning cabinet for rapidly cleaning small work is described in a recent folder of Pangborn Corp. Full information on the operation of this machine is presented; many drawings and pictures are included. Bulletin Je-68.

Homo Tempering
Leeds & Northrup Co. introduces a specialized Homo furnace for tempering heavy, dense loads of small particles. Production can be multiplied as much as four times. Complete description is given in Bulletin Je-46.

Carburizing Boxes
Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Kanthal Alloys
S.K.F. Steels, Inc., offer a descriptive booklet on Kanthal alloys. Certain of these alloys may be used as resistance elements; others are for furnace parts or other heat resisting applications. Full details are given in Bulletin Je-78.

Structural Bronze
Olympic Bronze, a high copper alloy containing silicon and zinc, is suggested by Chase Brass & Copper Co. for structural and engineering purposes. A new booklet gives many interesting details about its use. Bulletin M-59.

Copper Welding Rods
American Brass Co. describes in complete detail the welding properties and individual characteristics of 14 different copper alloy welding rods. The 16-page booklet also makes specific recommendations of welding procedure. Bulletin Je-89.

Heat Controller
As a companion instrument to their new indicating pyrometer, Foxboro Co. has introduced a new and inexpensive temperature controller which is dependable and easy to operate. Close control of temperatures is possible. Bulletin Mr-21.

Atmosphere Furnaces
An interesting folder of Surface Combustion Corp. gives performance data on their atmosphere furnaces in actual production bright annealing of ferrous and non-ferrous metals and carburizing, nitriding, forging and hardening without scale. Bulletin De-51.

Pickling Inhibitors
A pamphlet describing the nature and use of Grasselli Inhibitors is offered to those interested in pickling. A feature is a table of inhibitor strengths recommended for pickling various steels. Bulletin Ap-95.

Zinc Plating

Those interested in plating will find interesting material in a booklet of the R. & H. Chemicals Dept. of du Pont which describes plating with Duozinc, a mercury-containing zinc anode with marked production properties. Bulletin Ar-29.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Cold Drawn Shafting

Union Drawn Steel Co. has an interesting and attractive booklet on cold finished shafting. The complete story of its manufacture is told, and recommendations for specific applications are given. Bulletin Ar-83.

Nickel Cast Iron's Uses

The role of nickel and nickel-chromium cast iron parts in such applications as fabricating sheet metal, pressing and forging is interestingly explained in a new pamphlet of International Nickel Co. Bulletin Ag-45.

Oxwelding Stainless

Linde Air Products Co. has published a handbook of instructions for successfully welding corrosion resisting steels by the oxy-acetylene process. Welding procedures and weld treatments are carefully explained. Bulletin Jy-63.

X-Rays in Industry

General Electric X-Ray Co. has available a profusely illustrated brochure which gives the complete story of the industrial applications of X-Rays, the modern inspection tool. Bulletin Ma-6.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Controlled Steels

Carnegie Steel Co. has published a very interesting booklet which describes in some detail the process control used in the production of uniform steels. Bulletin Je-85.

Titanium in Steel

The use of ferro carbon-titanium in steel is thoroughly described in a booklet of Titanium Alloy Mfg. Co. Titanium's application in forgings, castings, rails, sheets and plates is interestingly explained. Bulletin M-90.

X-Rayed Alloy Castings

Electro Alloys Co. describes their X-Ray inspection of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Bulletin Oc-32.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a booklet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

New Tempering Furnace

American Electric Furnace Co. has a new, low-priced electric air tempering furnace. It heats to 600° F. in 5 min. and to 1000° F. in 15 min., transferring heat to work 50 times faster than still air and 6 times faster than salt. Bulletin Mr-2.

Air for Furnaces

Users of gas or oil-fired furnaces know the necessity for a dependable source of large volumes of air at low pressures. A generously illustrated folder of Spencer Turbine Co. shows why their Turbo-Compressors give unfailing, economical air service. Bulletin Mr-70.

18-8 Steels

Republic Steel Corp. has prepared a new 16-page booklet giving up-to-the-minute data on Enduro 18-8 stainless steels including their several special analyses. Authentic metallurgical and fabricating information is given. Bulletin Je-8.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Localized Heat Treating

American Gas Furnace Co. offers information on production machines for localized hardening, tempering or annealing of tools, saws, springs, screws and machine parts of all kinds, using gas as fuel. Bulletin Ag-11.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Properties of Stainless

Carpenter Steel Co. offers (to manufacturers in U. S. A. only) a handy pocket size slide chart which gives at a glance a summary of technical data on all Carpenter stainless steels. Bulletin Se-12.

Steel Specifications

A handy, up-to-date specification sheet for carbon and alloy steels is offered by Timken Steel & Tube Co. On one page are printed analyses of all important types of Timken steels. Bulletin Jy-71.

Carbonol Process

The Carbonol process of carburizing is described in detail in a folder of Hevi Duty Electric Co. Results are said to be quicker, cleaner and better cases at very low cost. Bulletin Jy-44.

Quenching Handbook

E. F. Houghton & Co. have published an excellent 80-page handbook on the subject of quenching. More than 30 charts and photomicrographs help tell the story. A copy will be sent free to those who request it. Bulletin Jl-38.

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